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**Yoshimura et al.**

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(54) **PROJECTOR DEVICE**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**  
**F21V 29/00** (2006.01)

(52) **U.S. Cl.** ..... **362/294**; 362/218; 362/345;  
362/373; 362/285; 362/287; 355/97; 355/98;  
355/61

(58) **Field of Classification Search** ..... None  
See application file for complete search history.

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(57) **ABSTRACT**

A liquid crystal projector device of the present invention includes a lamp unit and a lamp cooling fan, the lamp unit having disposed therein a columnar lamp bulb having a luminous body enclosed therein, the lamp unit having a side wall opposed to the lamp cooling fan and provided with a first and second air introduction openings at opposite sides of a plane including a central axis of the lamp bulb and perpendicular to the side wall, for introducing the air drawn from the lamp cooling fan toward the lamp bulb.

**2 Claims, 36 Drawing Sheets**

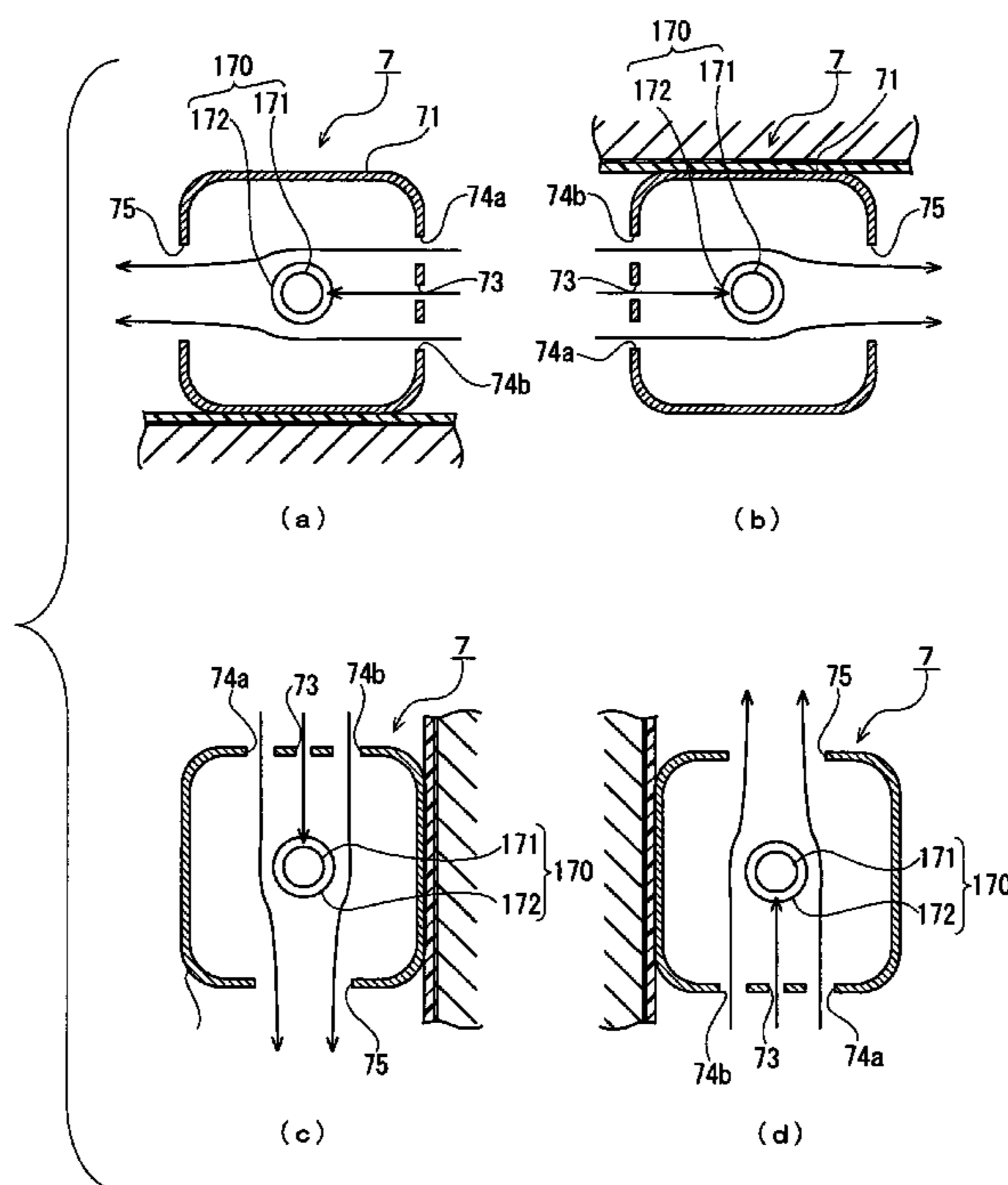


FIG. 1

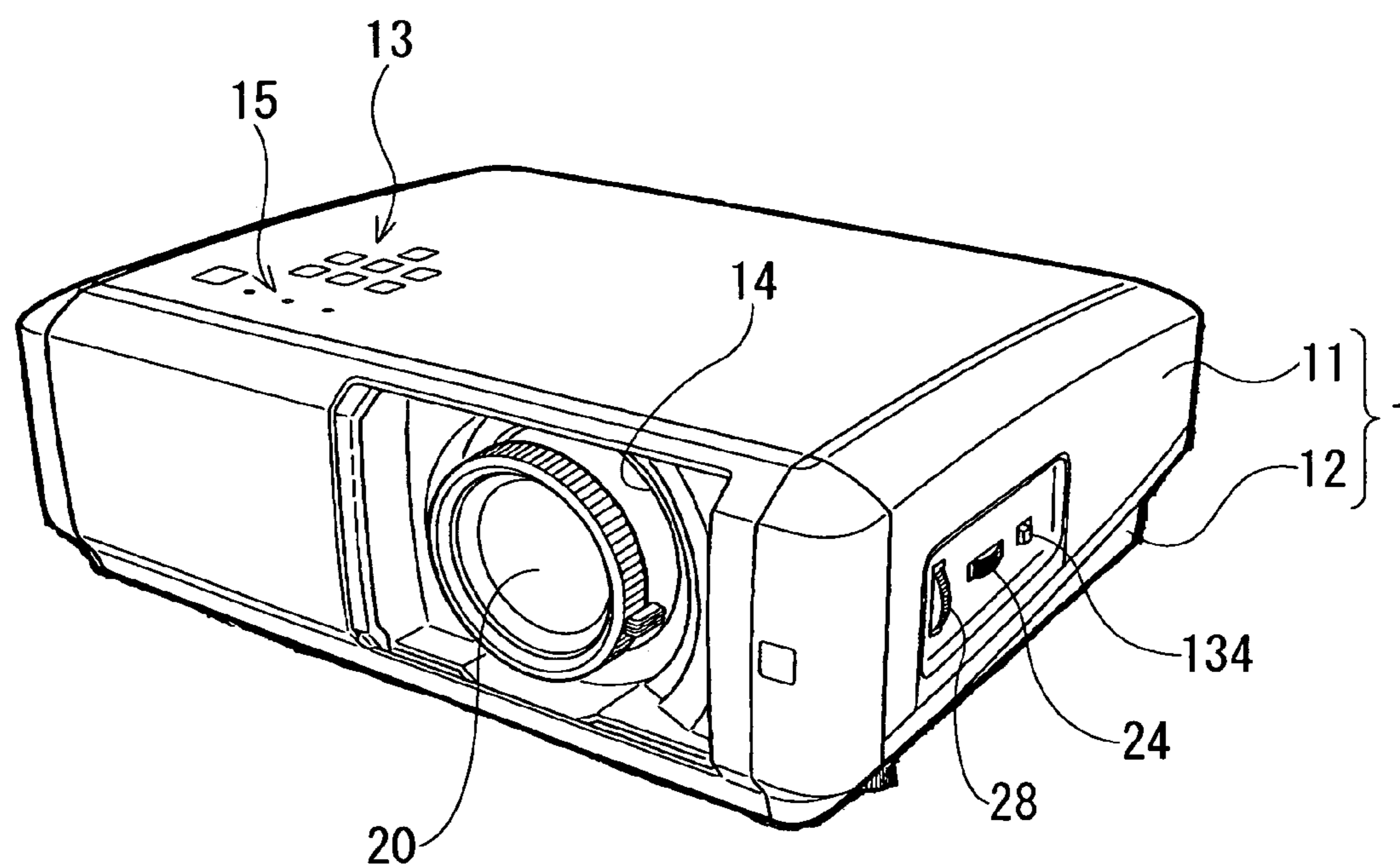


FIG. 2

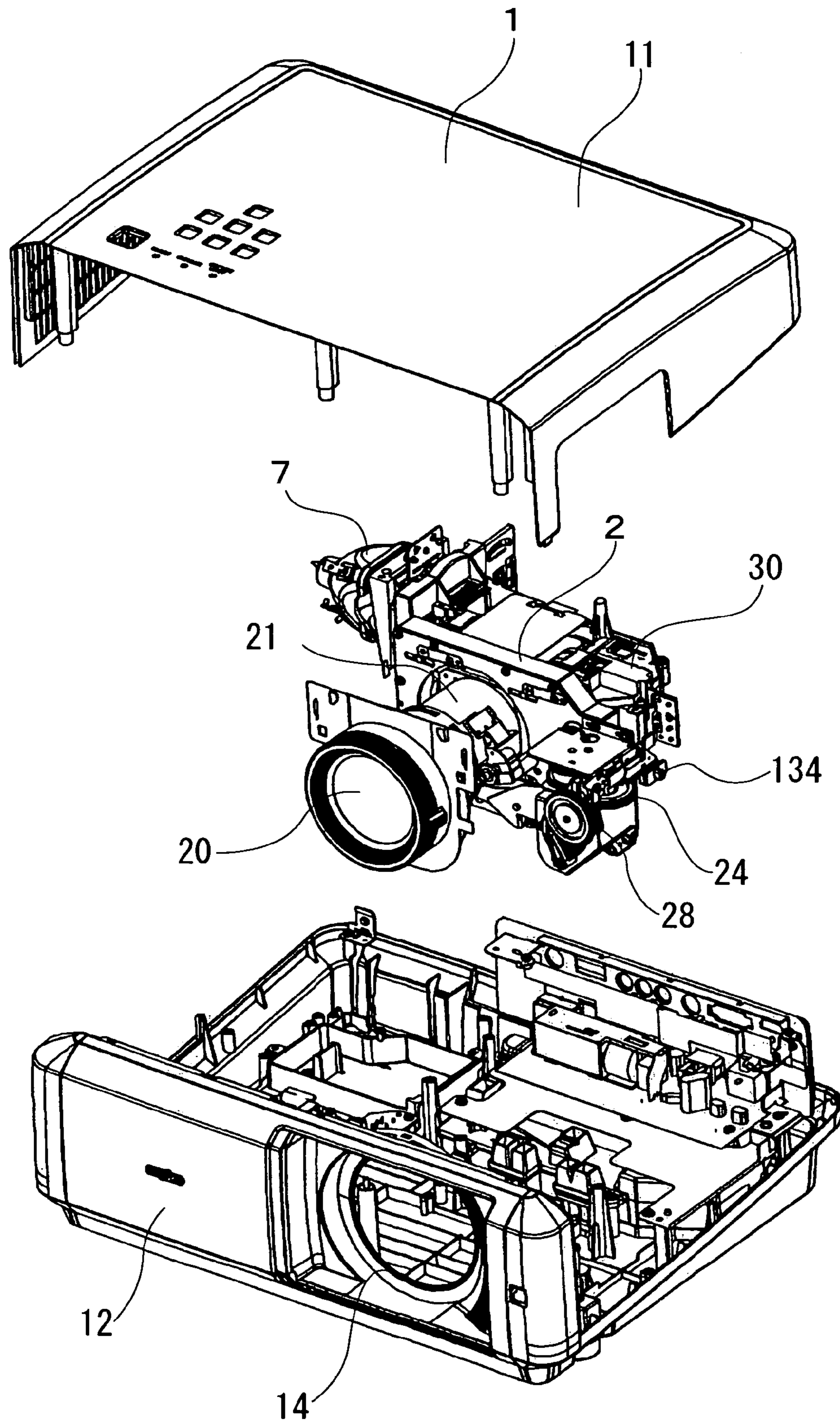




FIG. 3

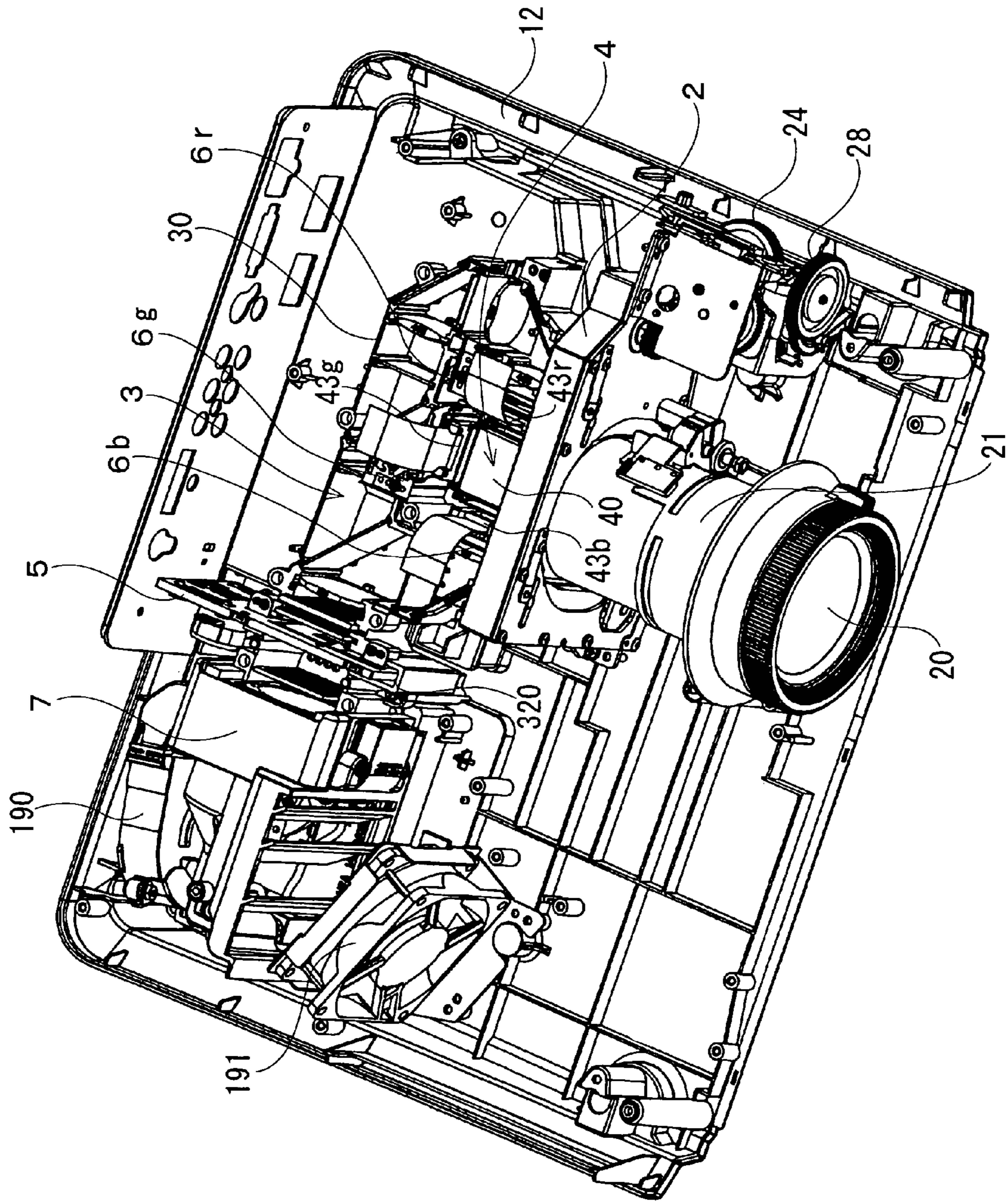


FIG. 4

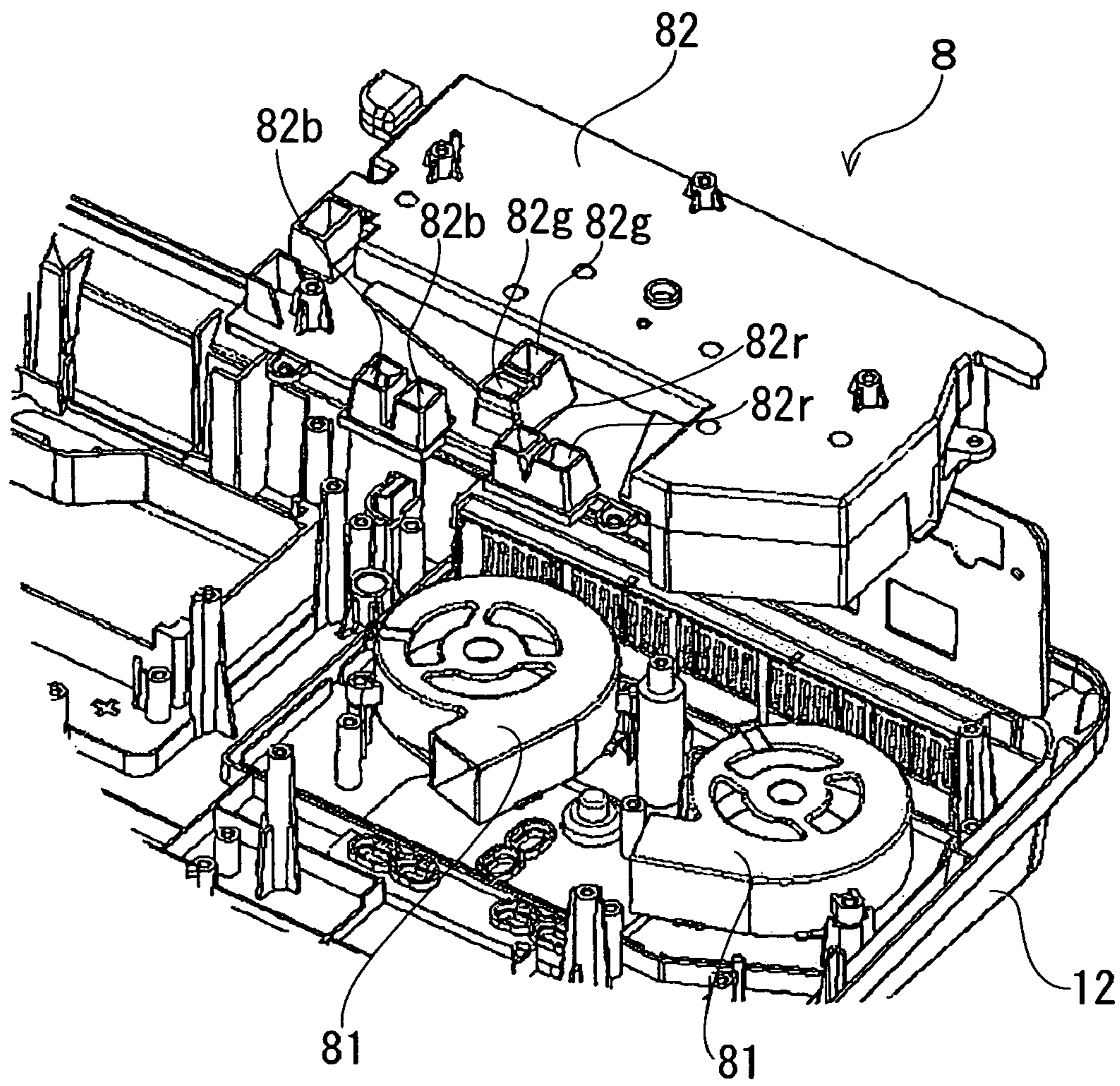






FIG. 6

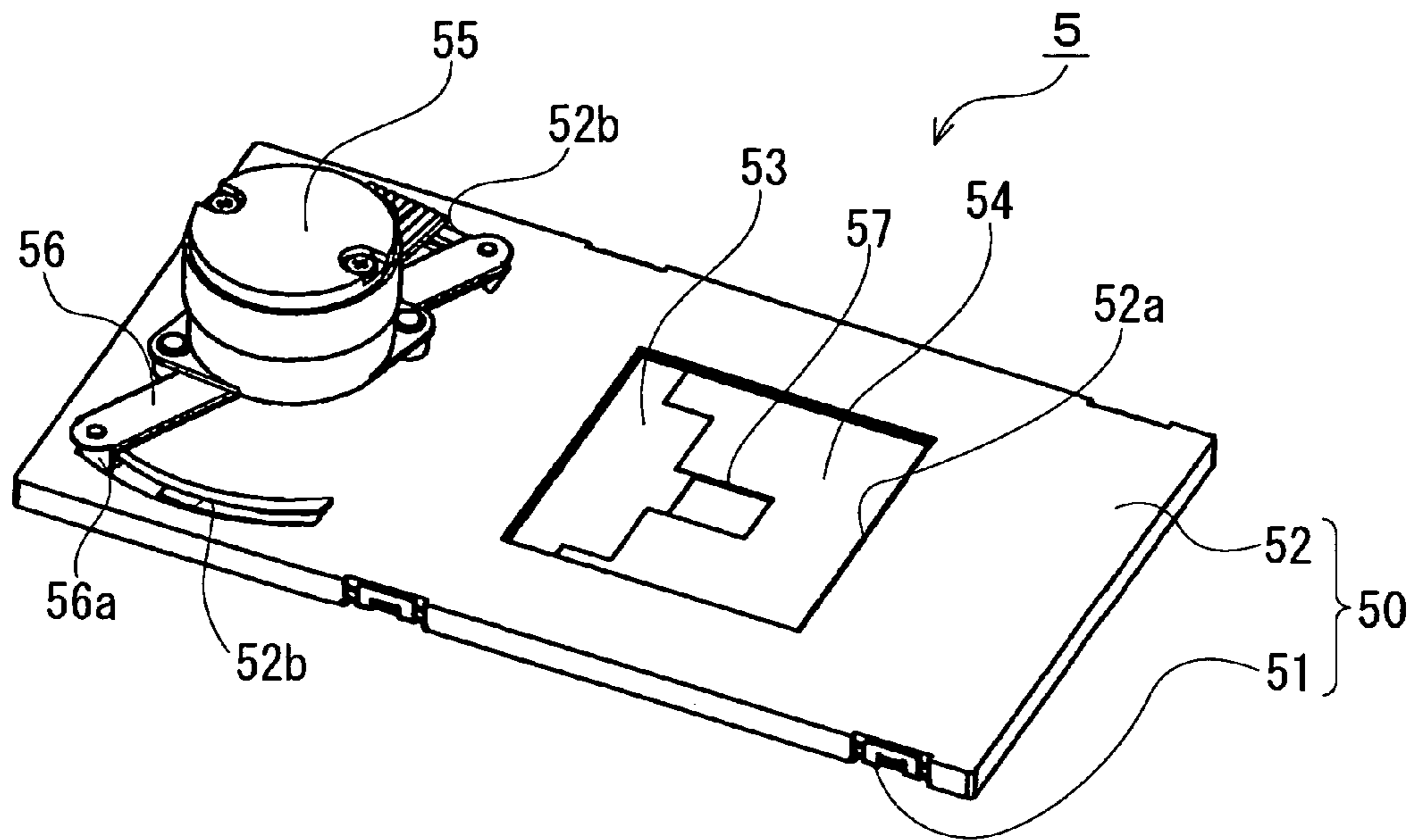


FIG. 7

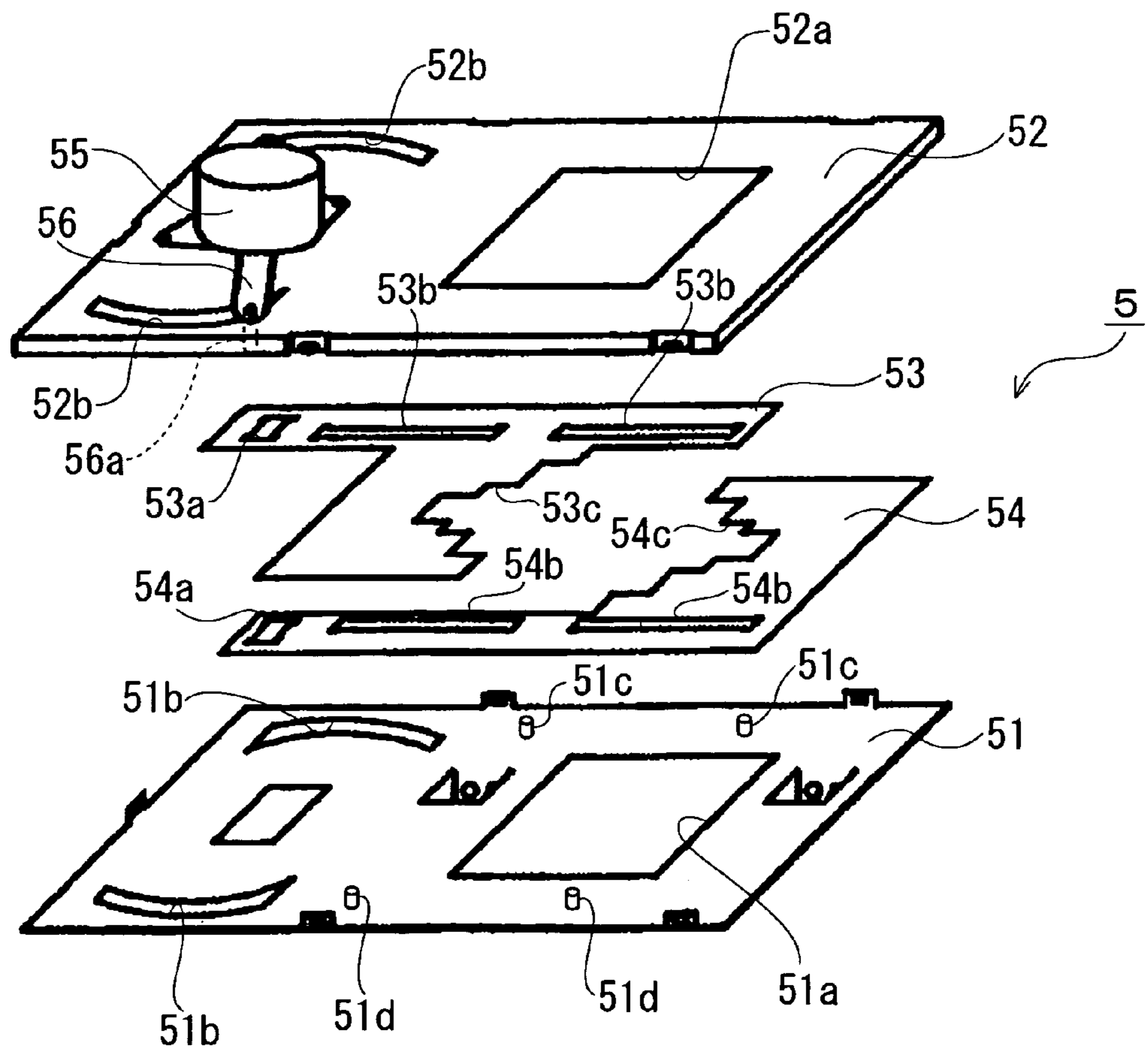


FIG. 8

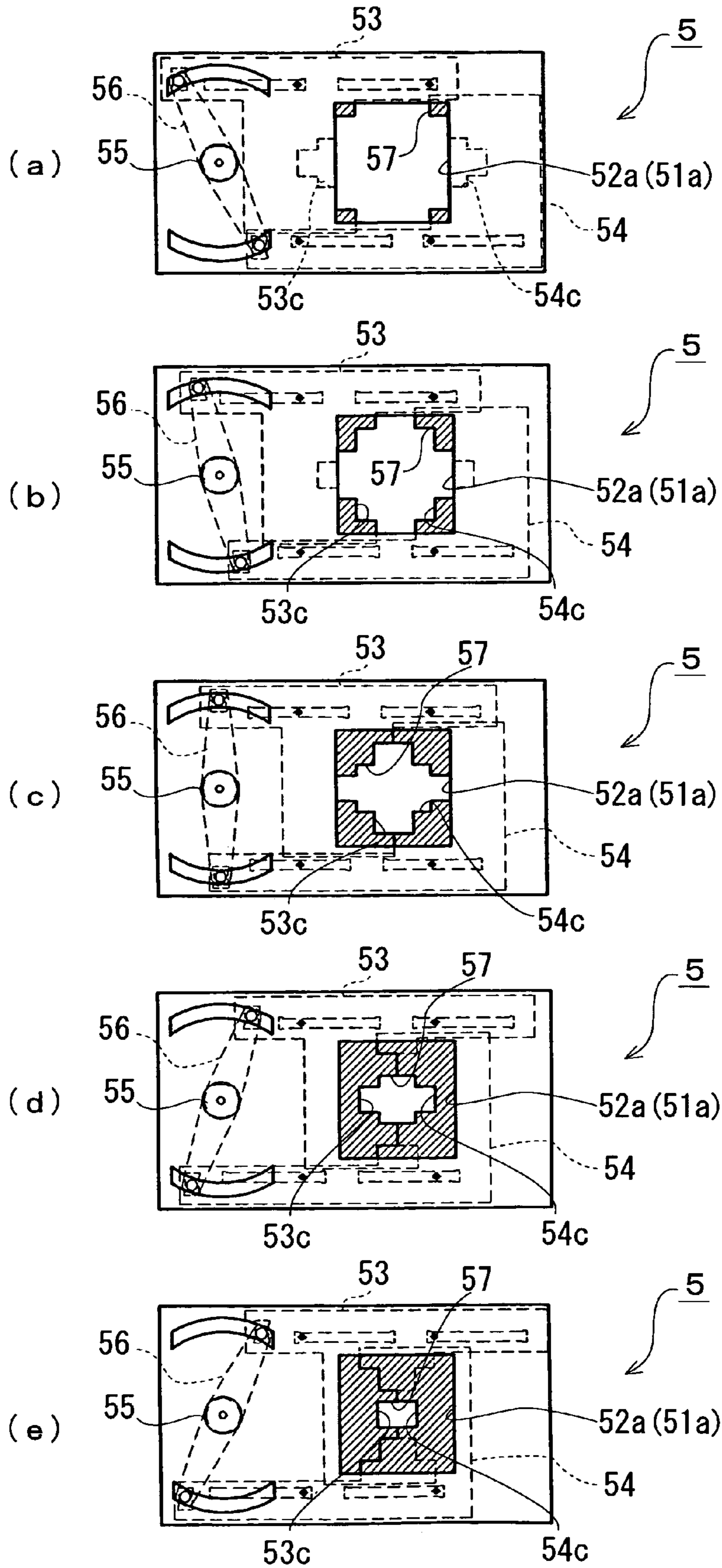
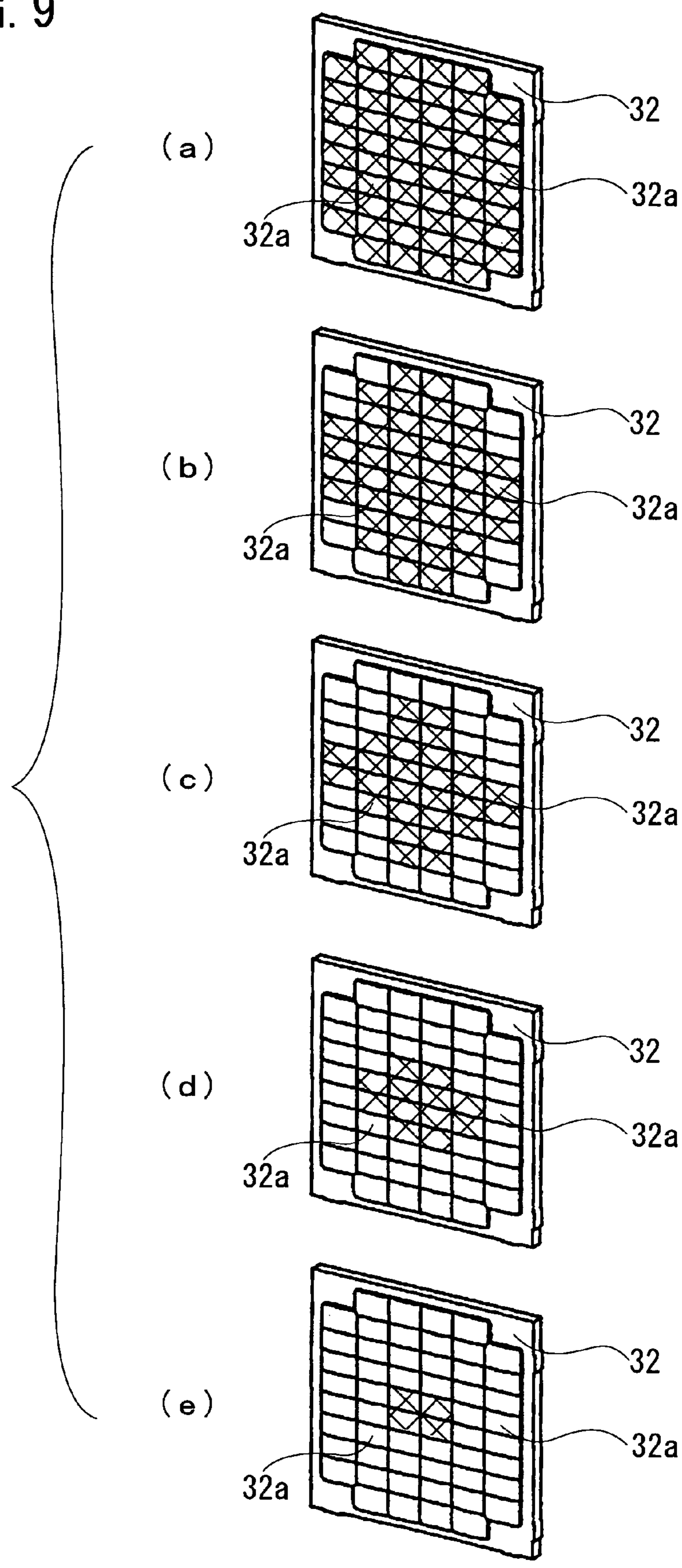




FIG. 9



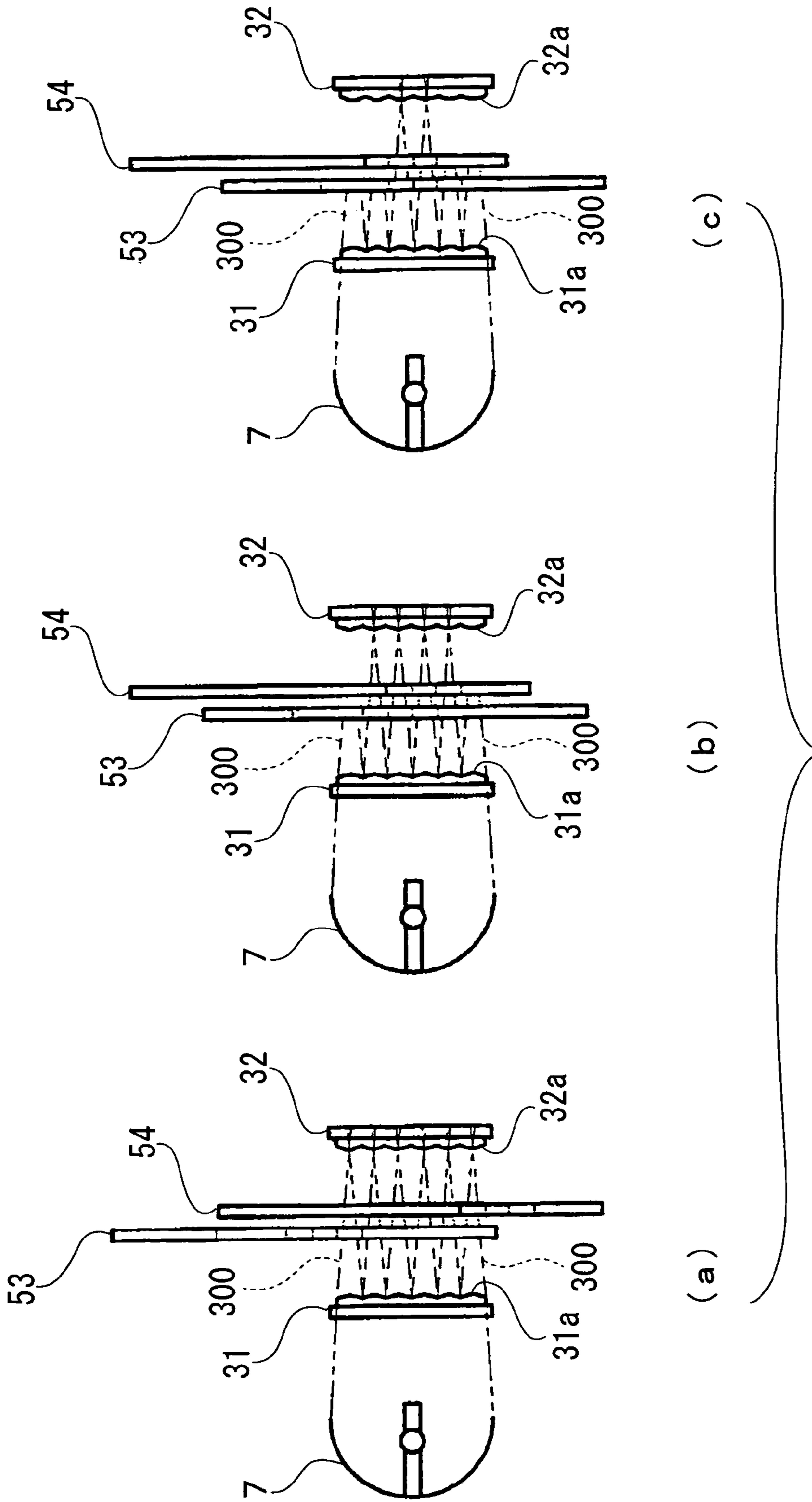


FIG. 10

FIG. 11

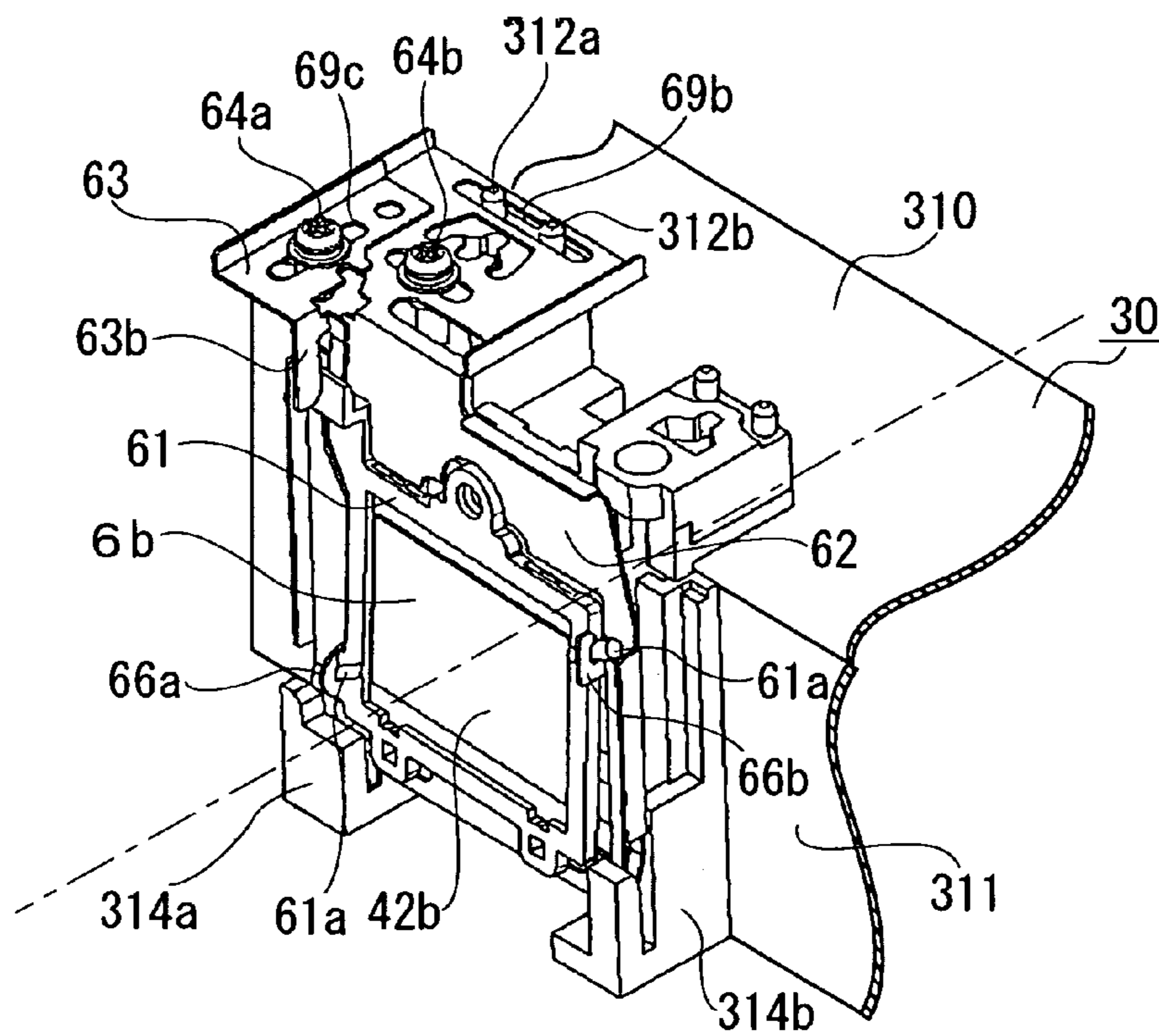
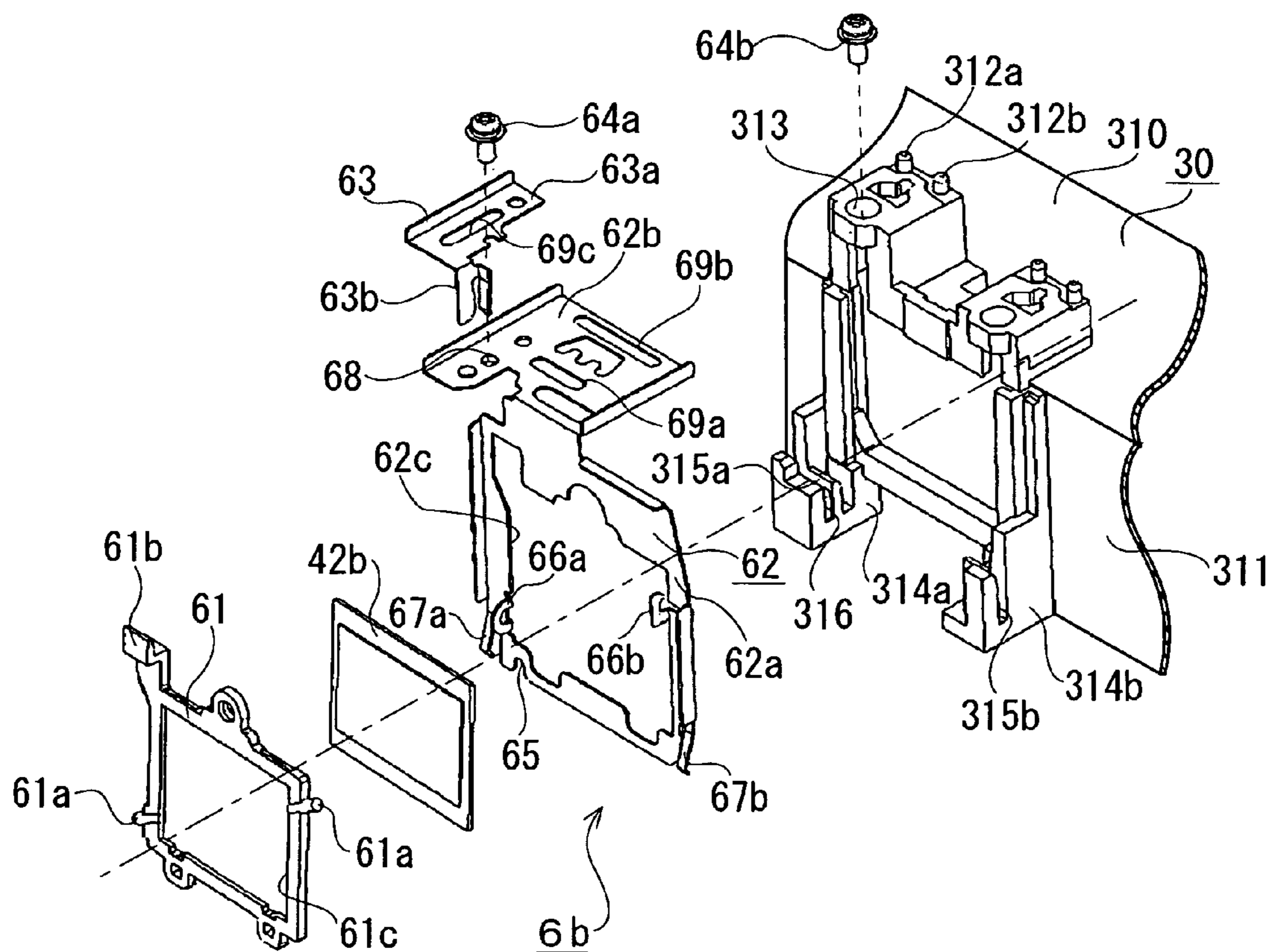


FIG. 12





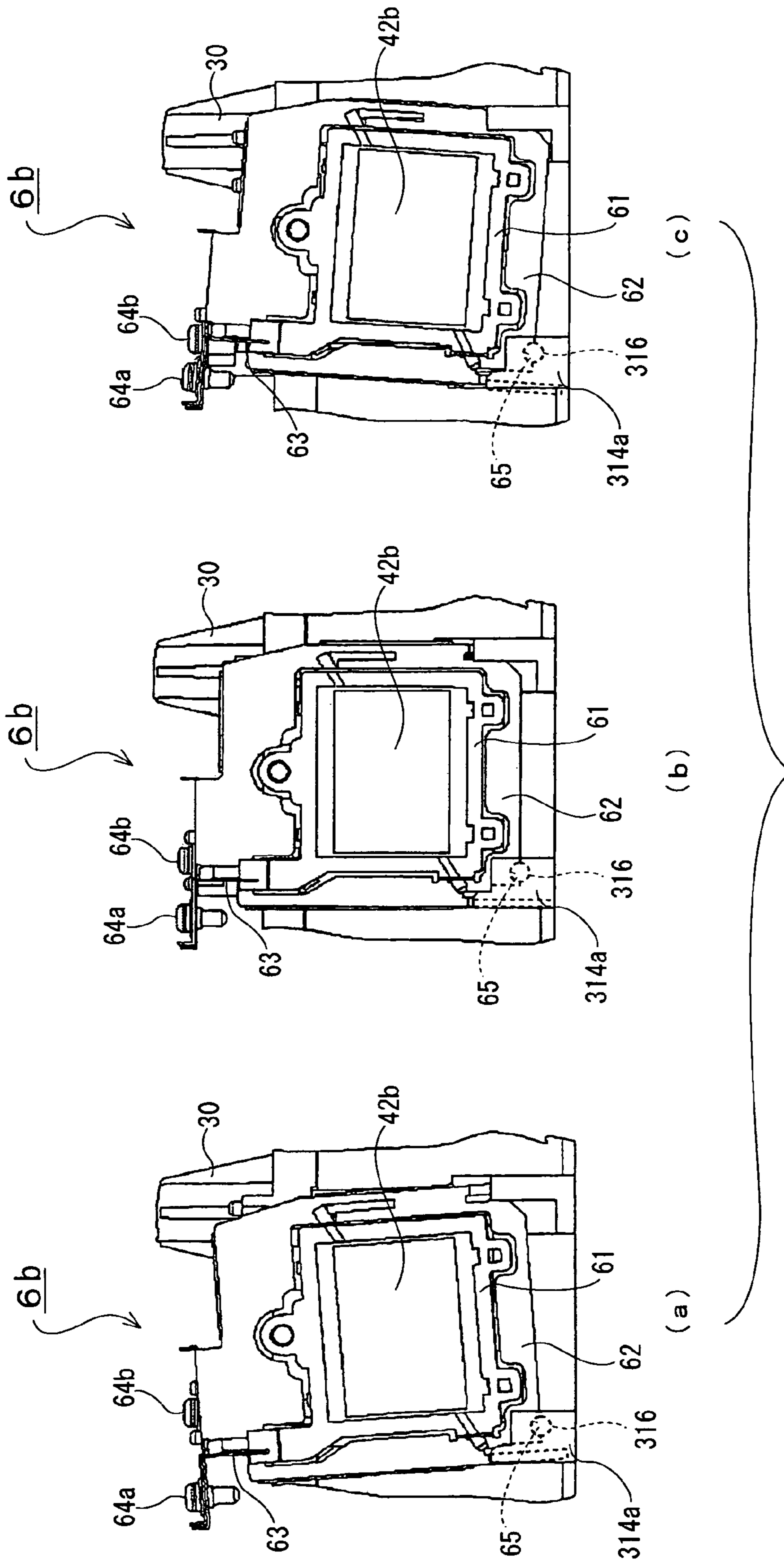


FIG. 13

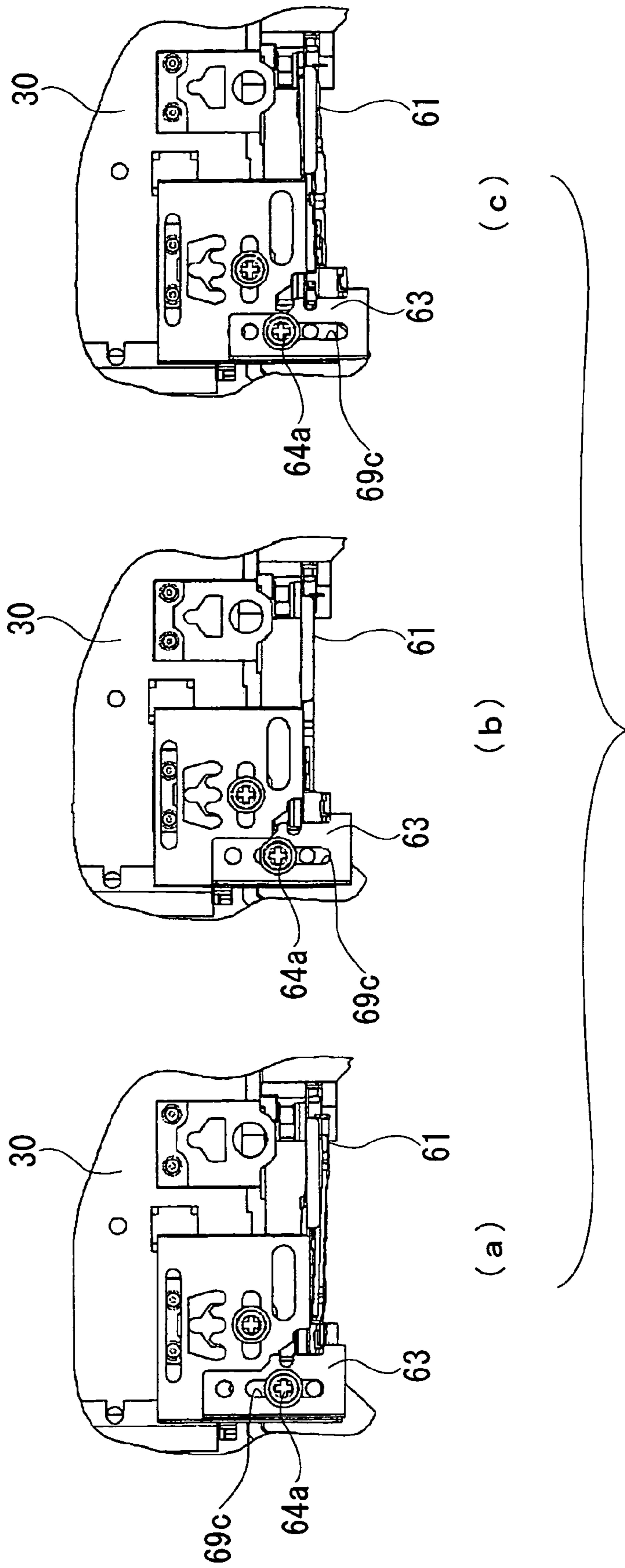


FIG. 14

FIG. 15

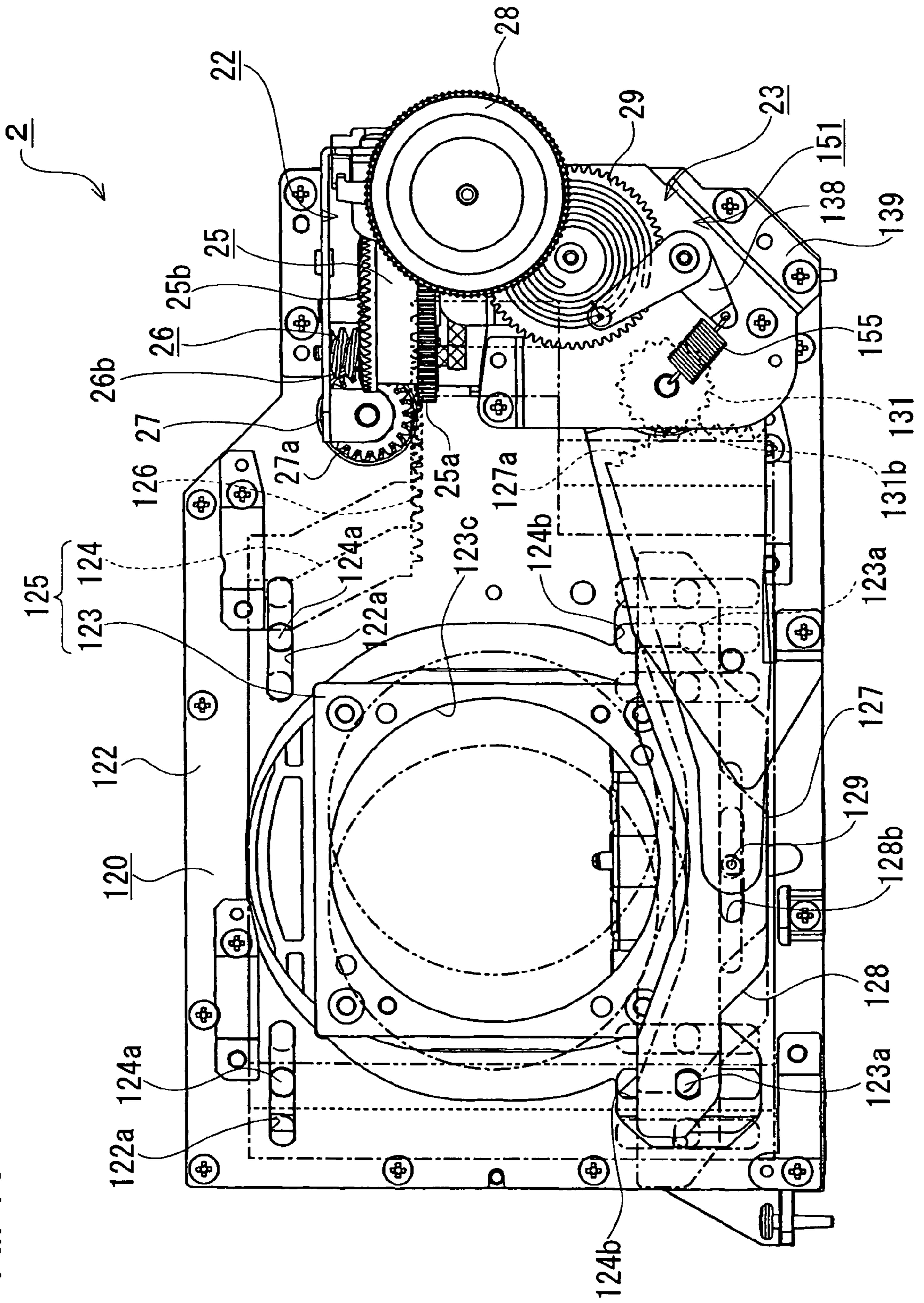




FIG. 16

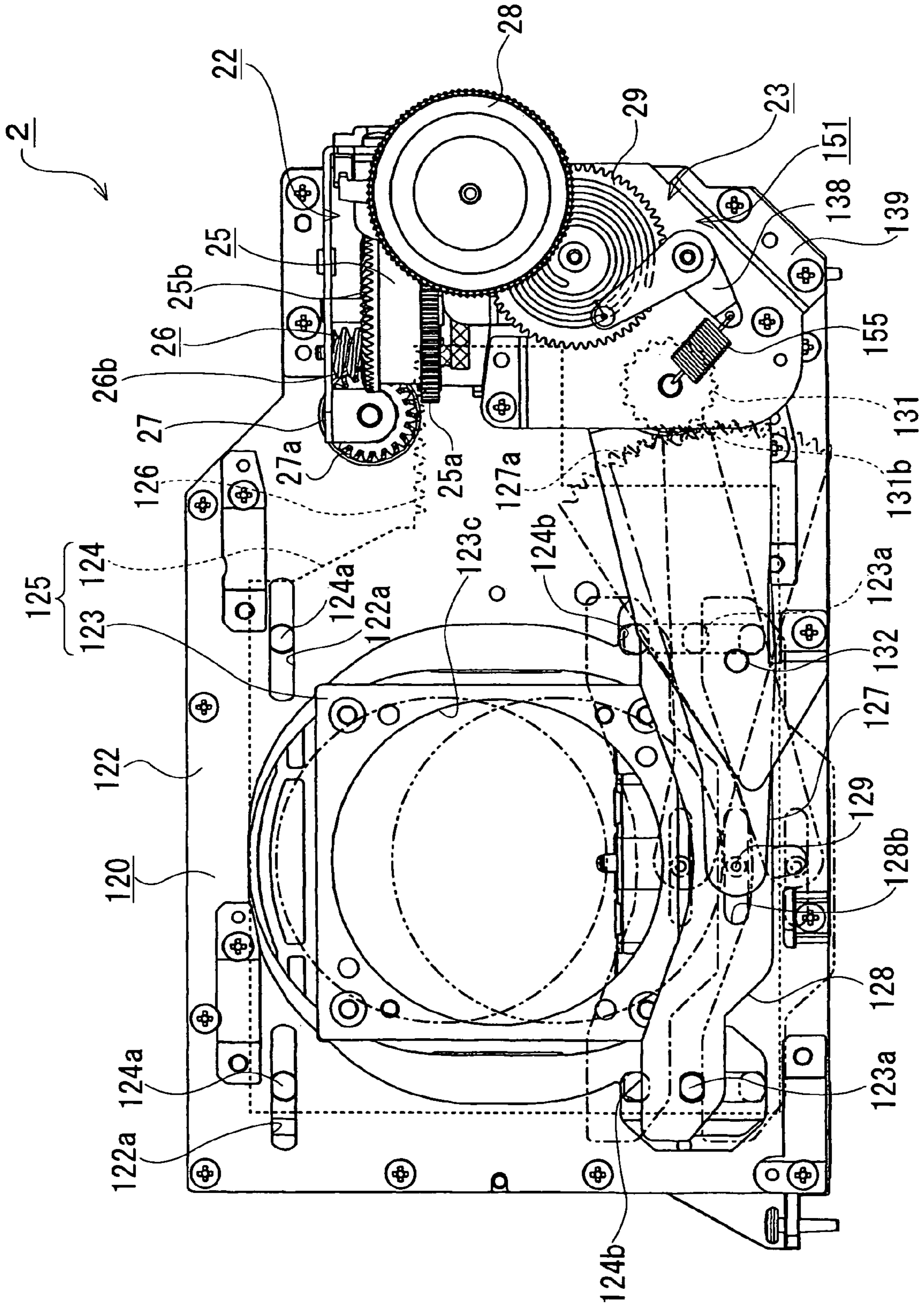








FIG. 19

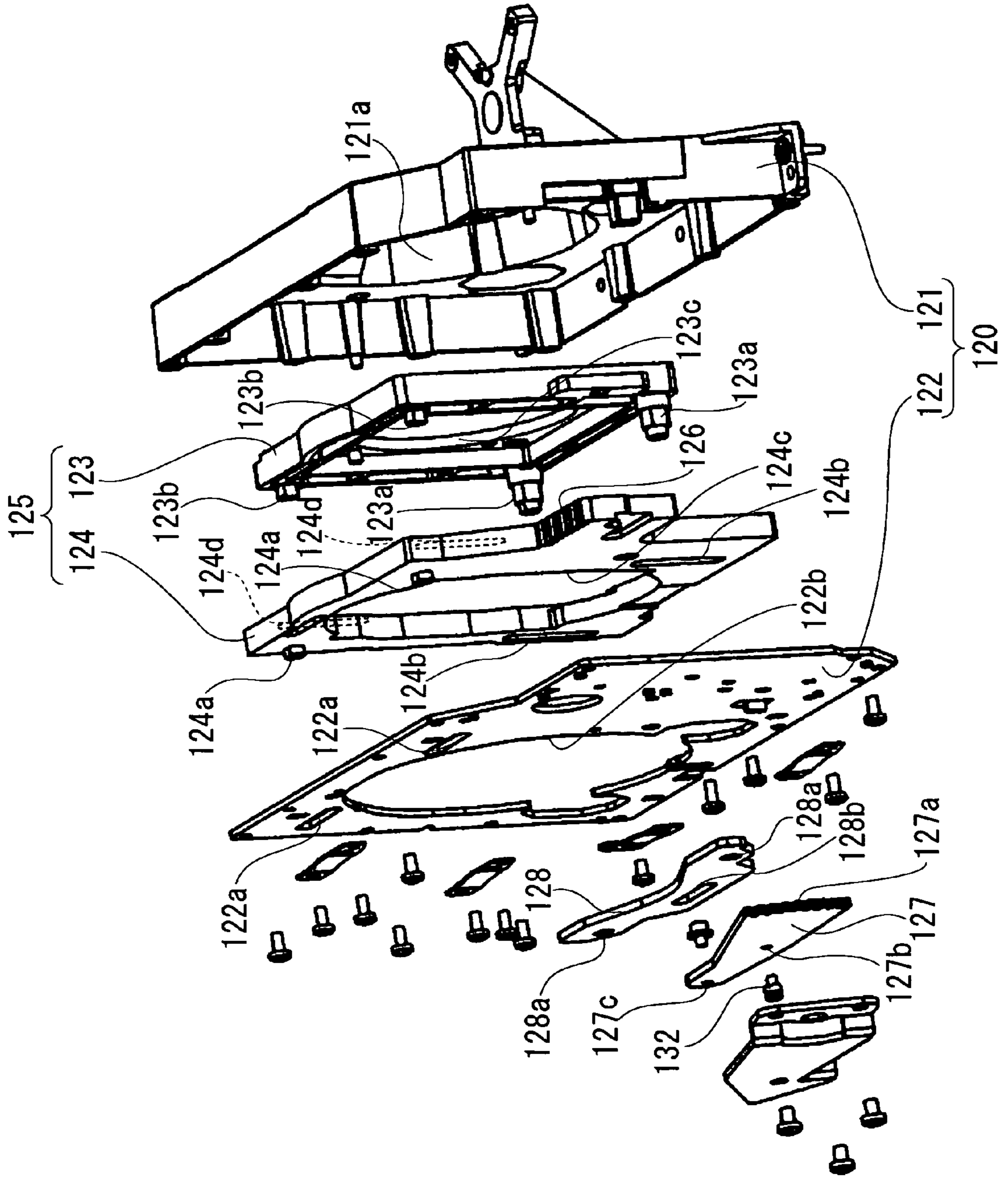


FIG. 20

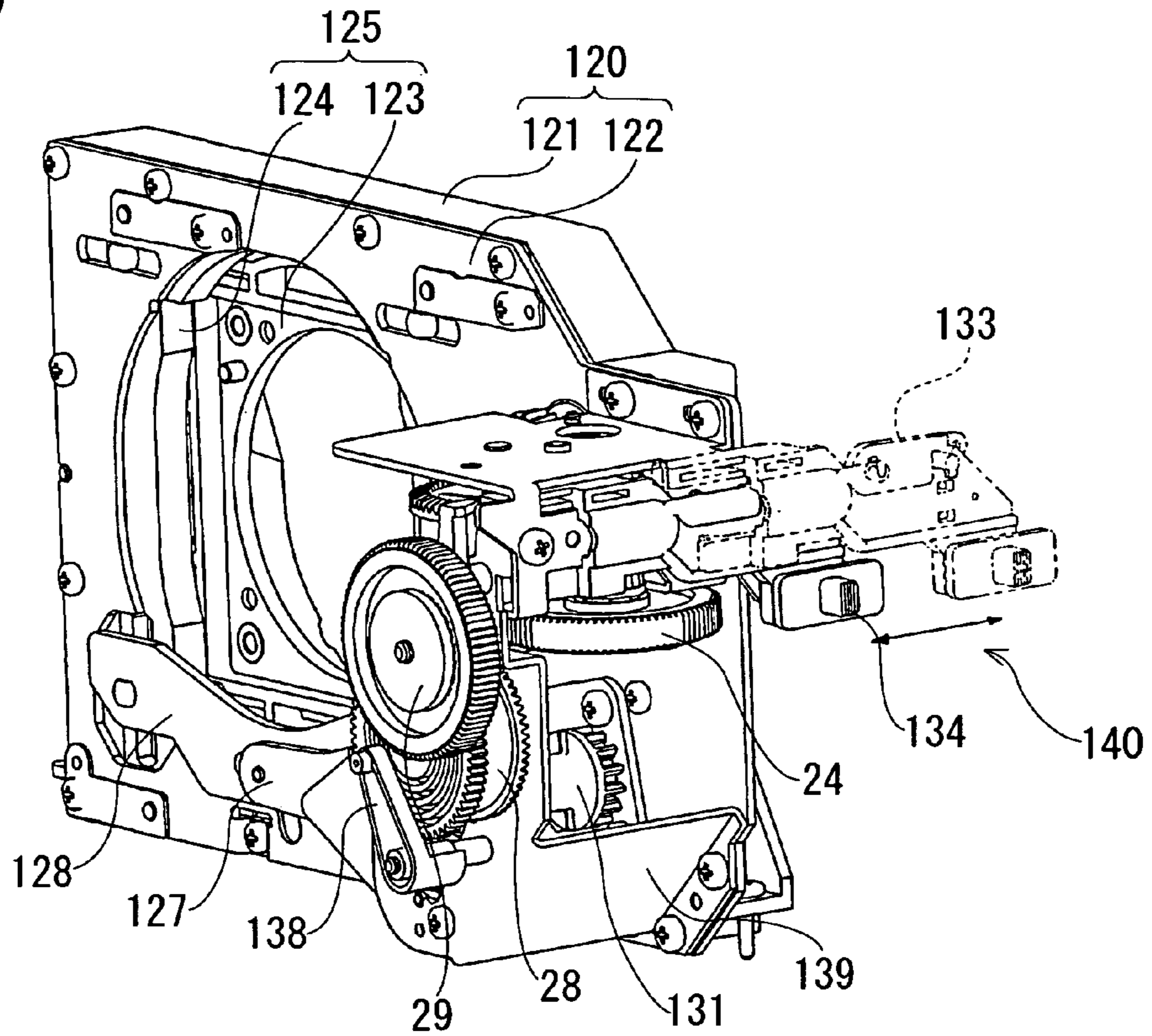


FIG. 21

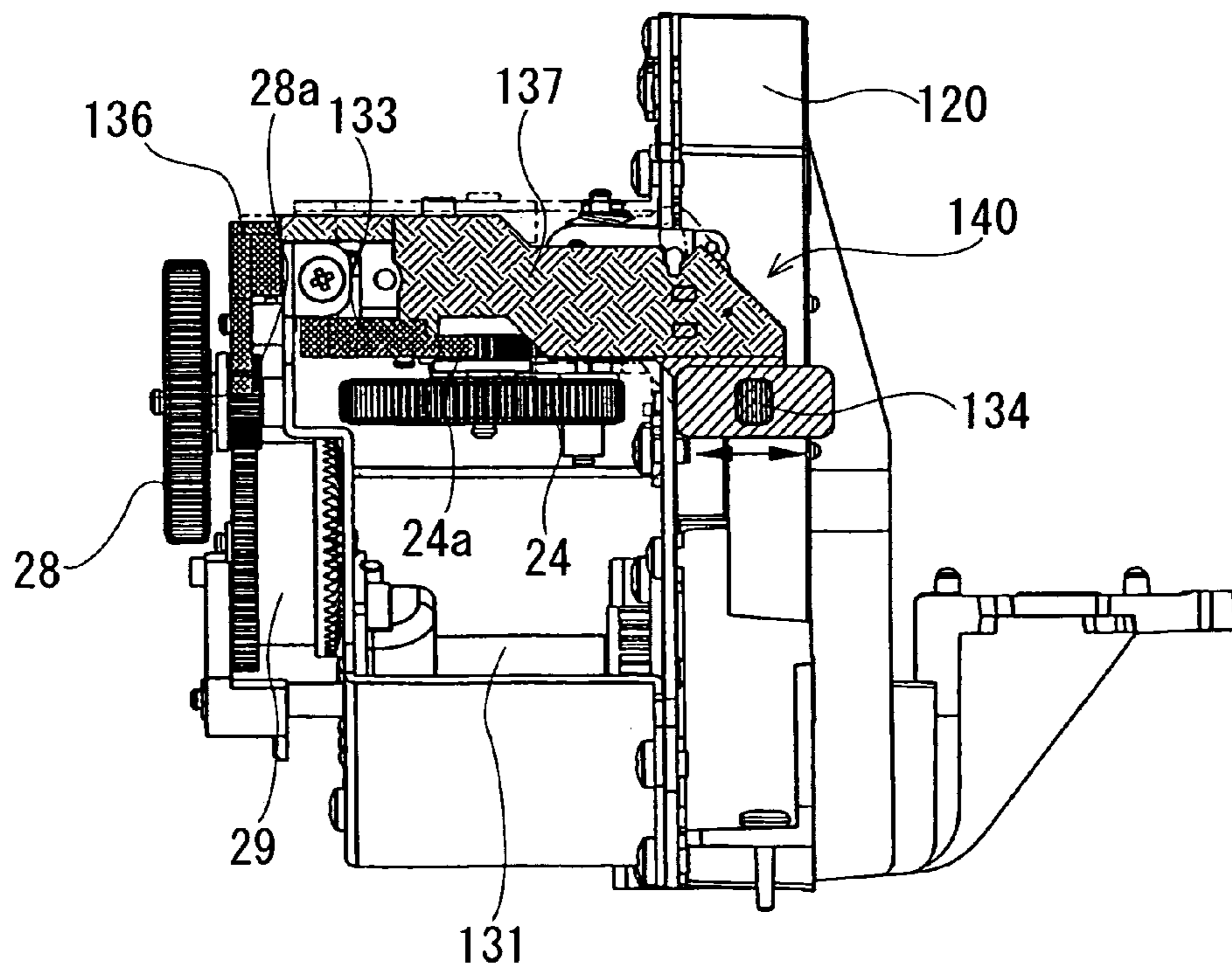


FIG. 22

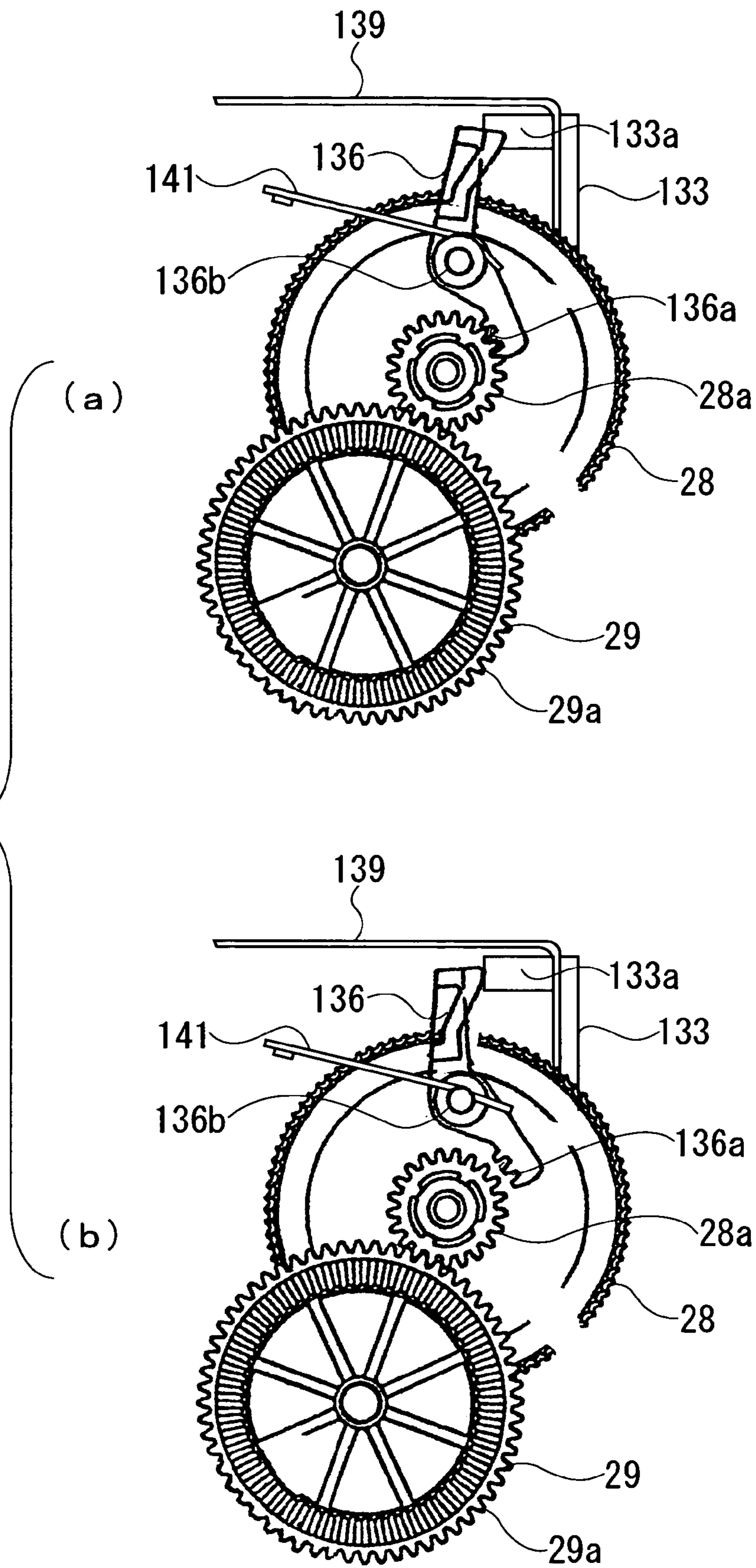




FIG. 23

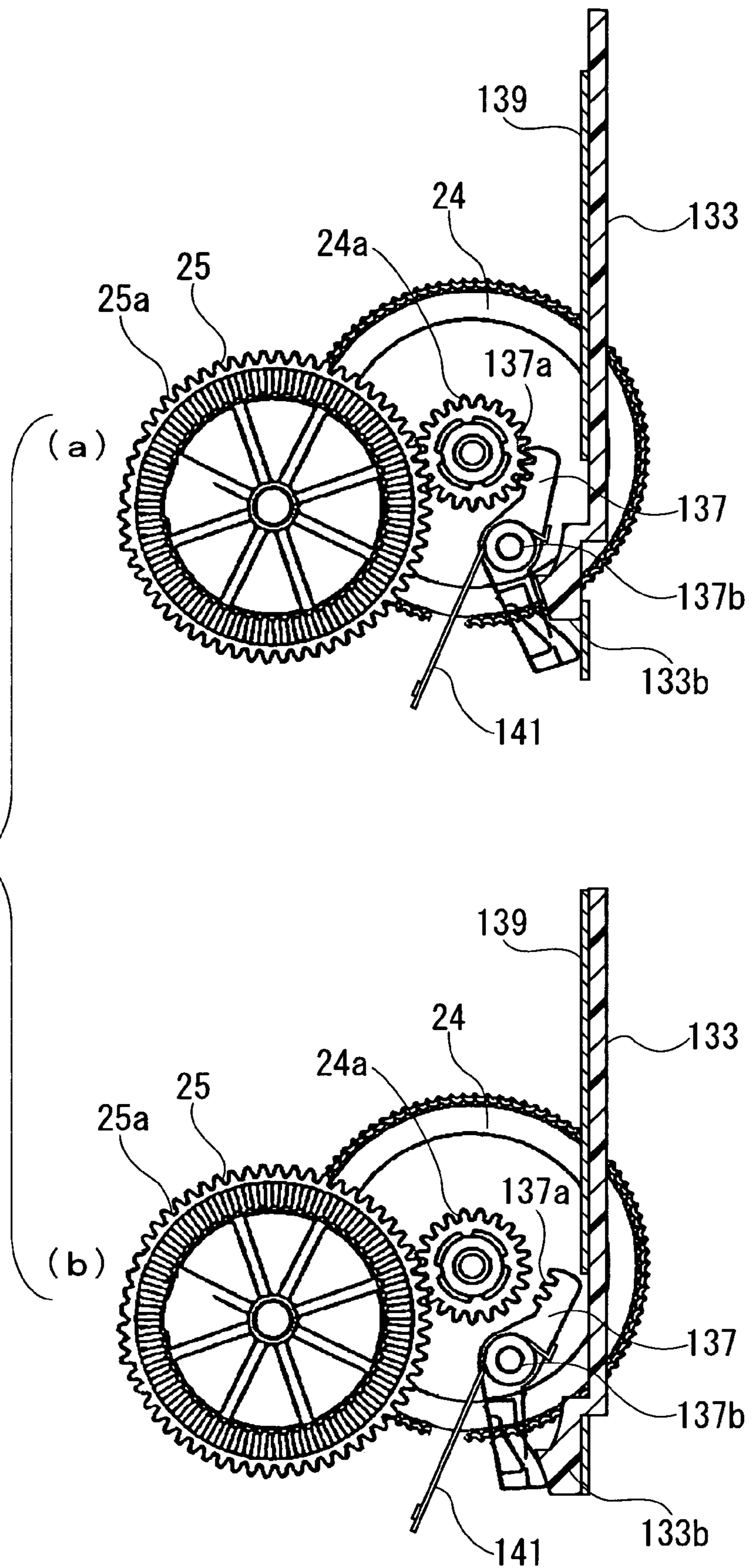


FIG. 24

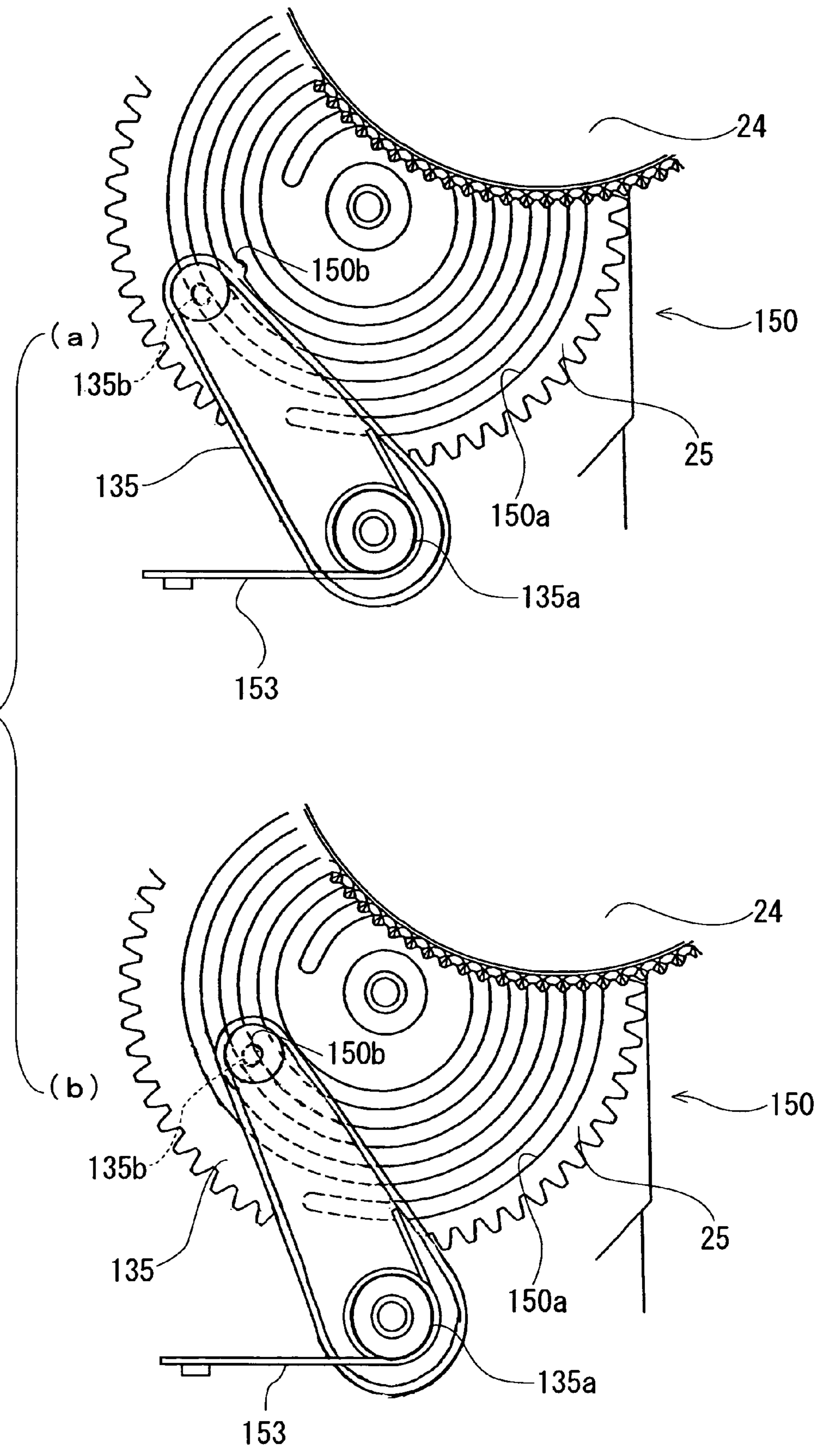


FIG. 25

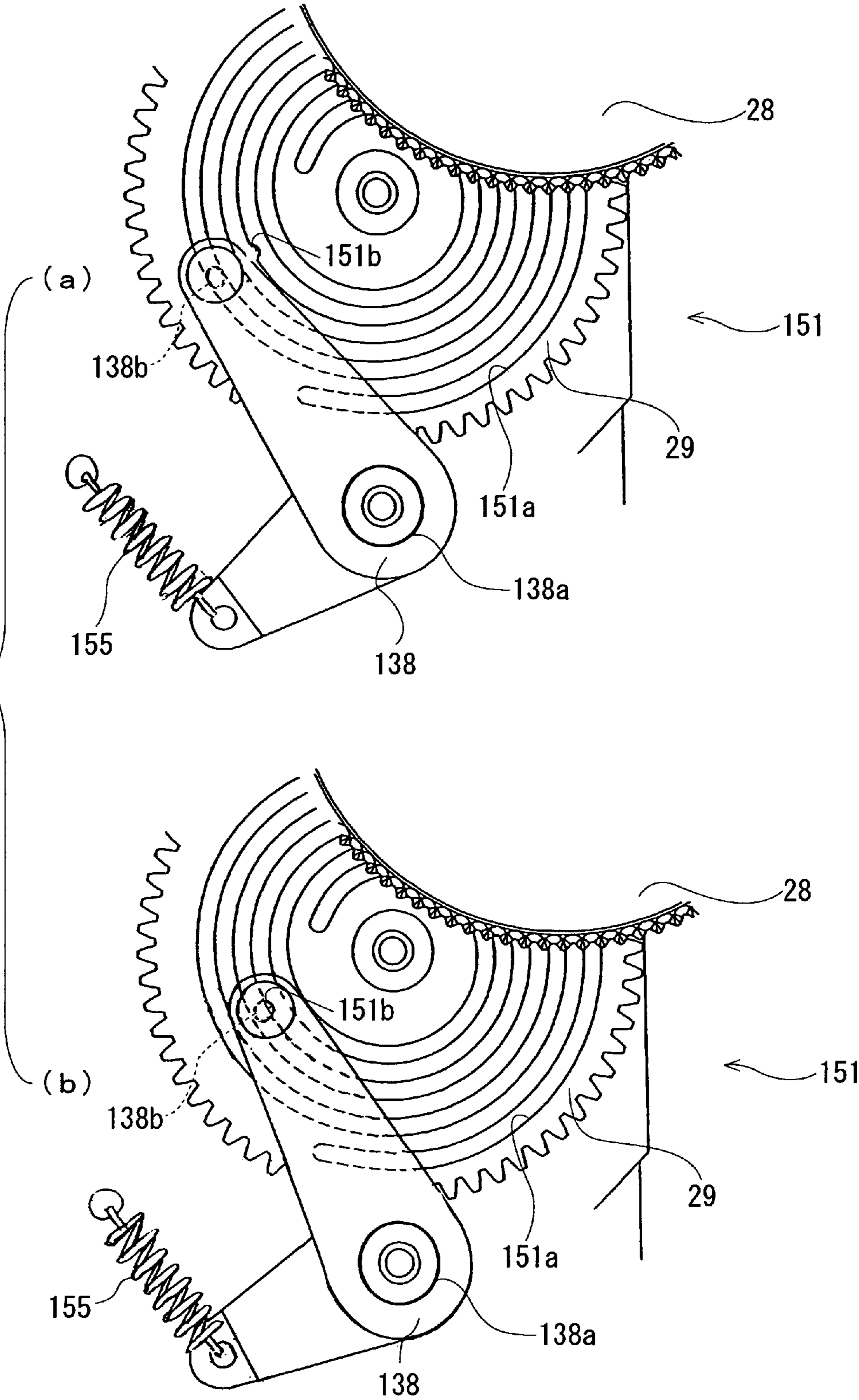




FIG. 26

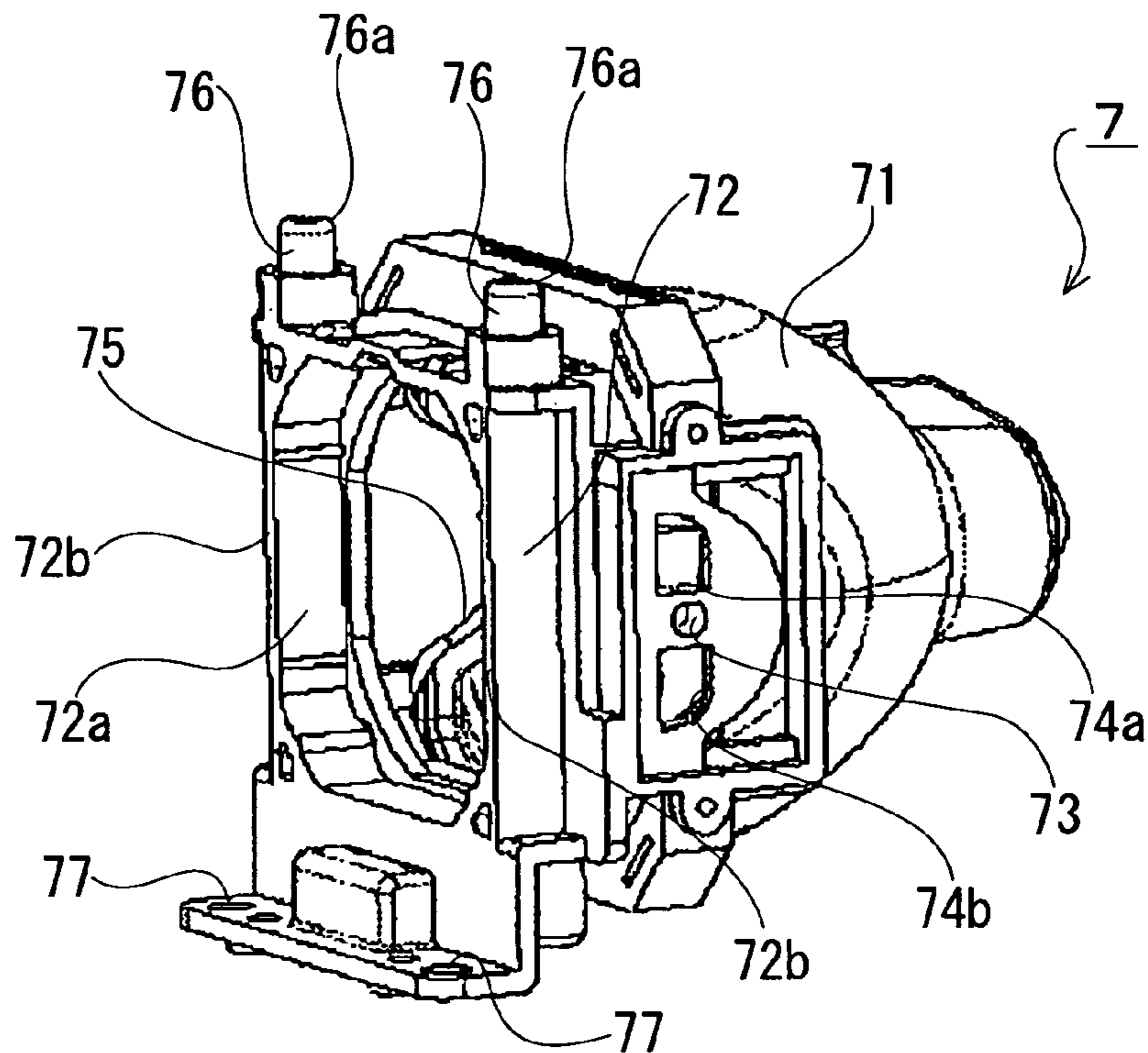


FIG. 27

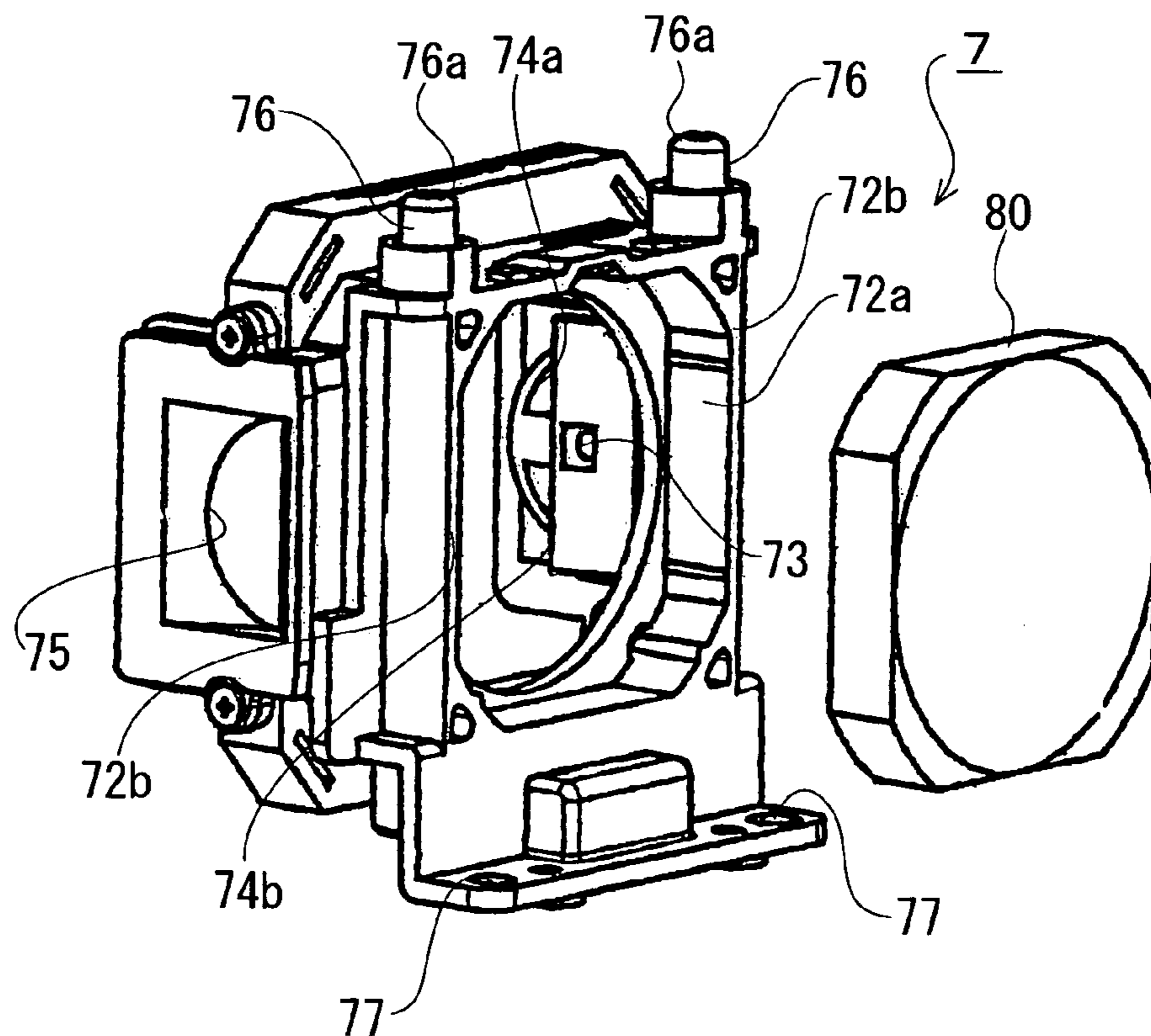


FIG. 28

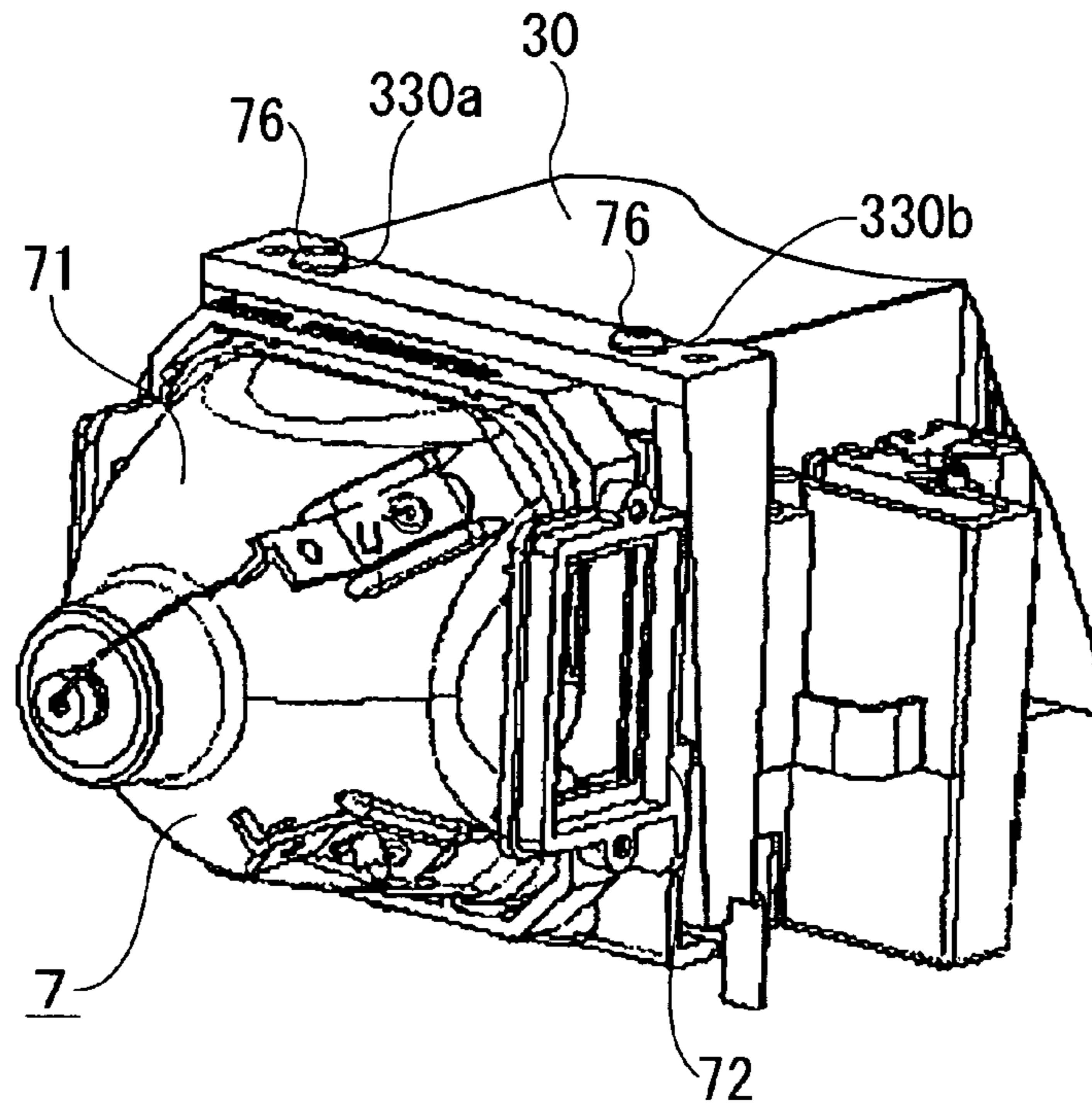


FIG. 29

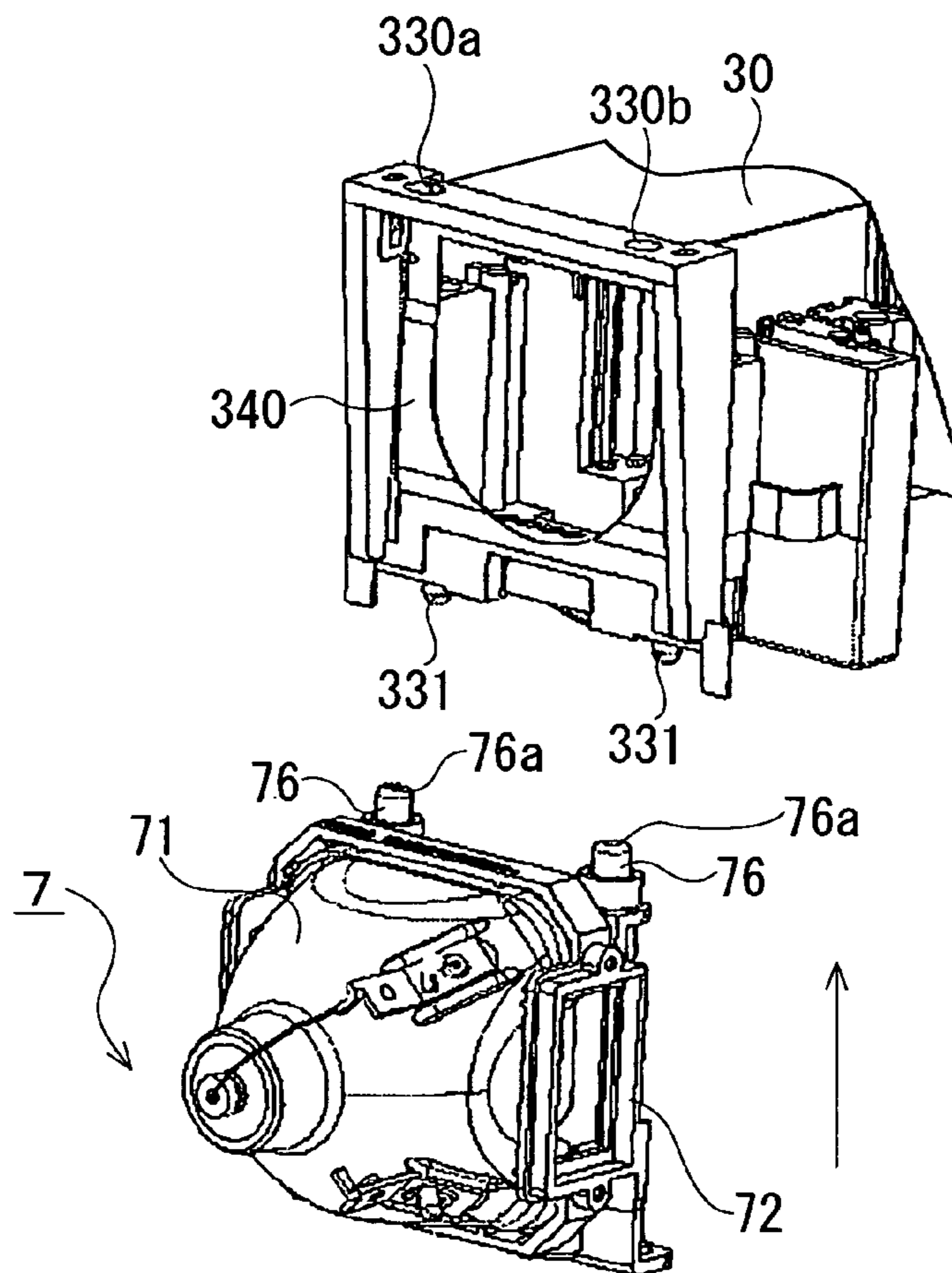


FIG. 30

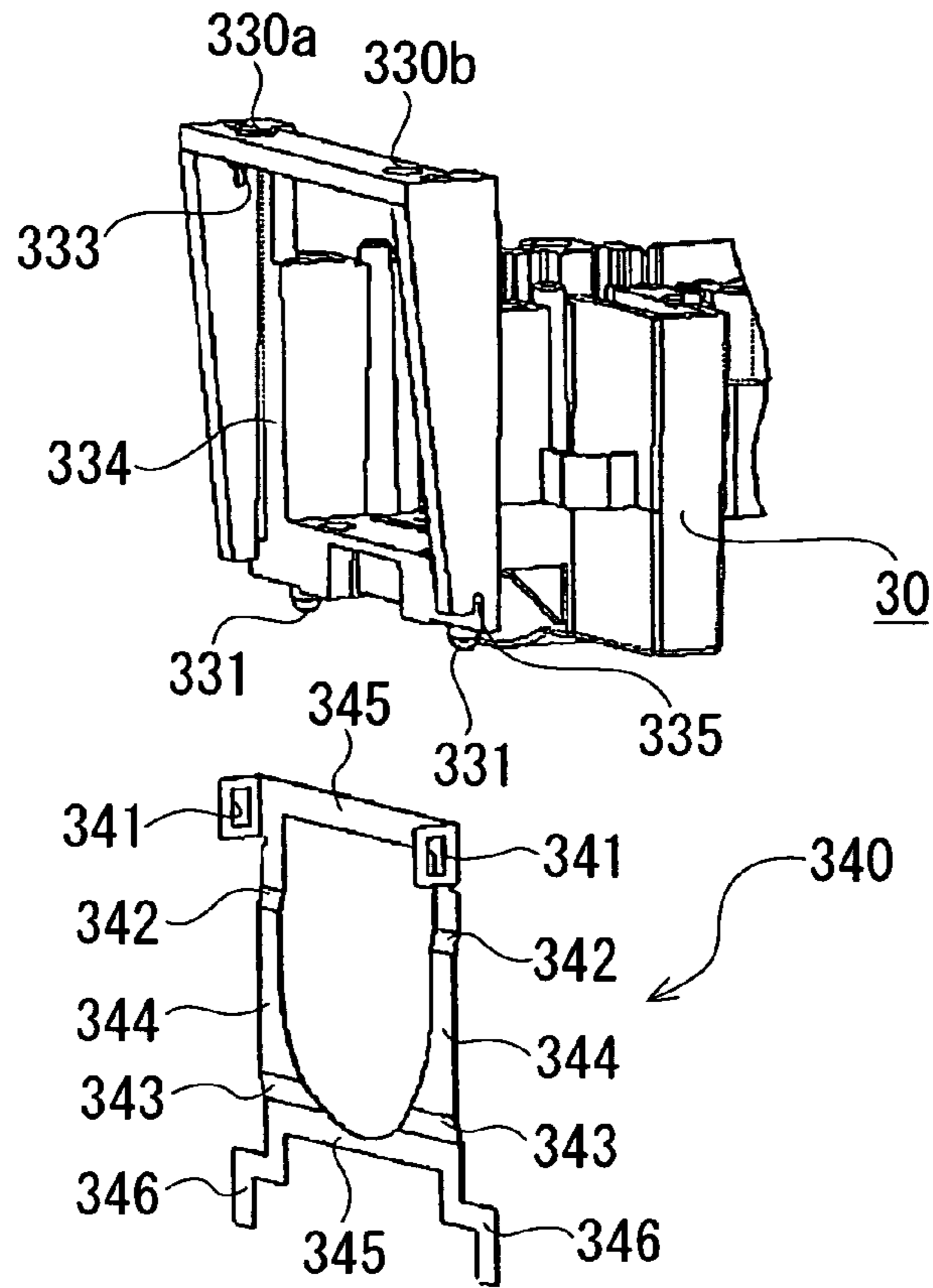


FIG. 31

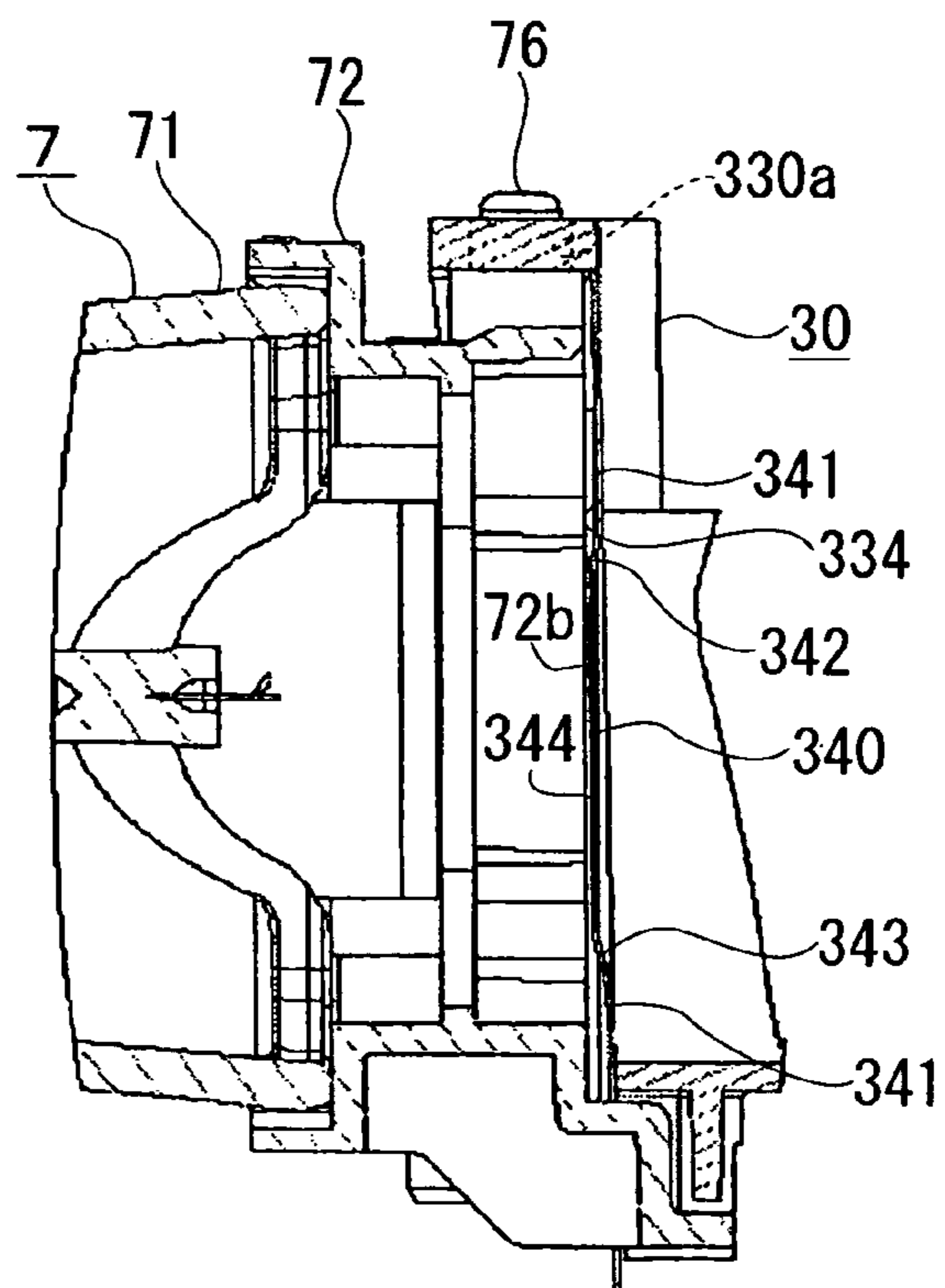




FIG. 32

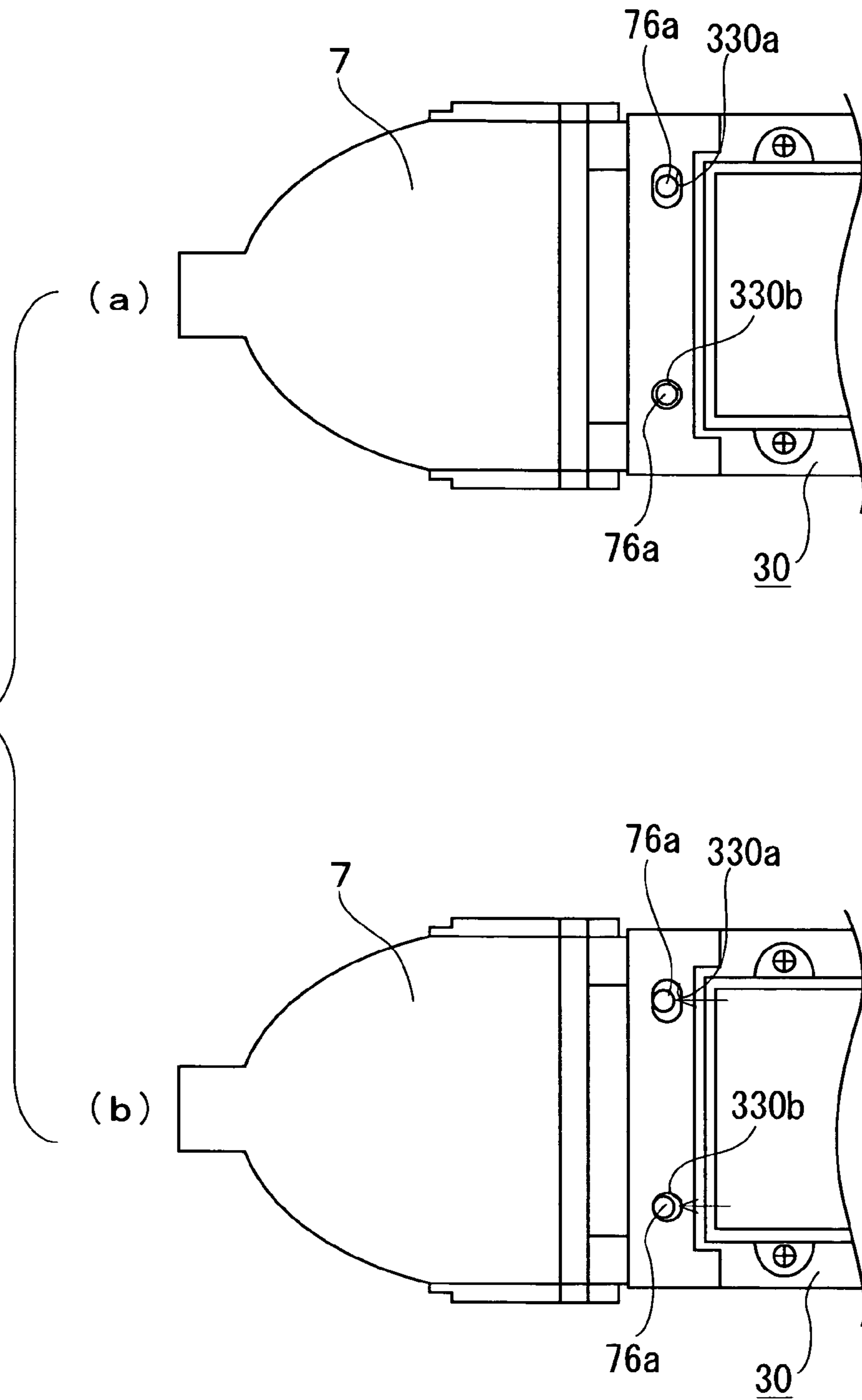


FIG. 33

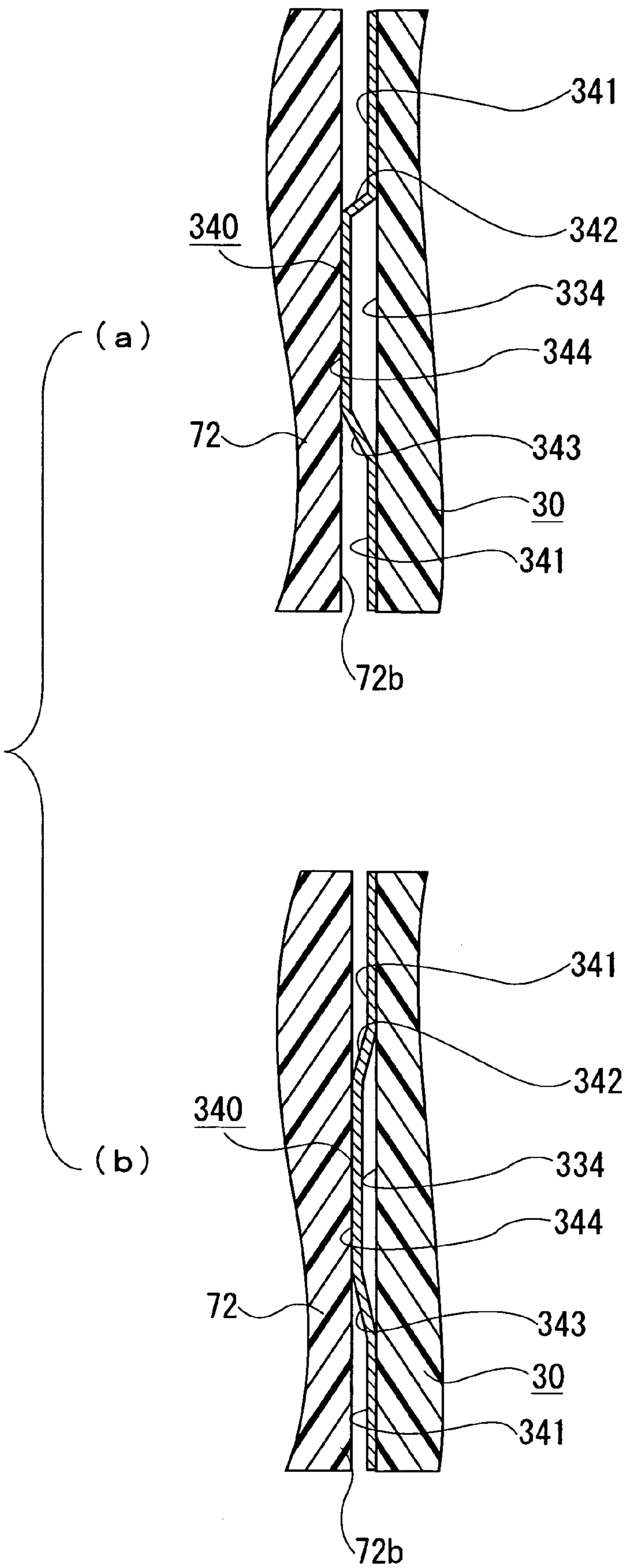


FIG. 34

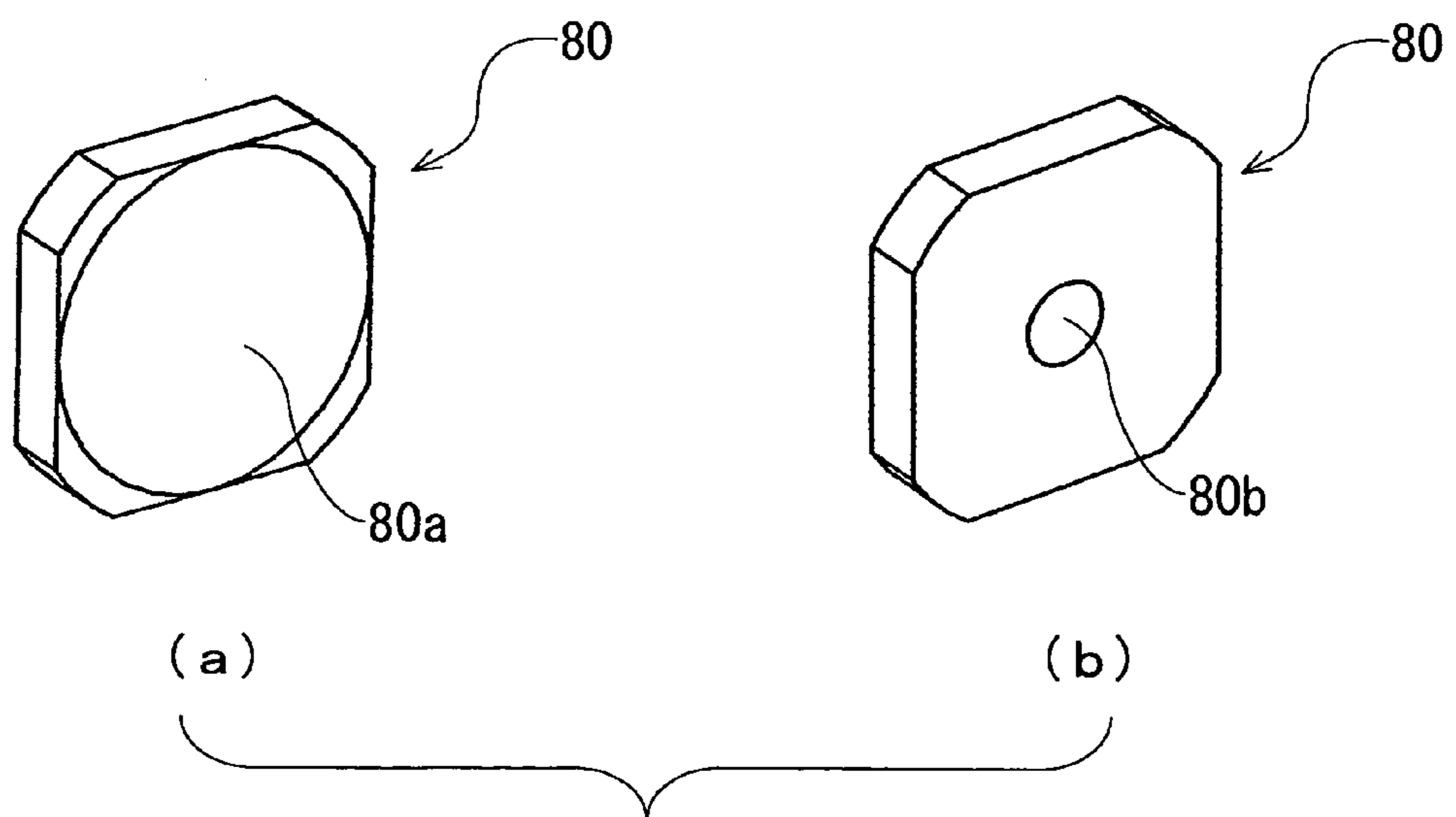
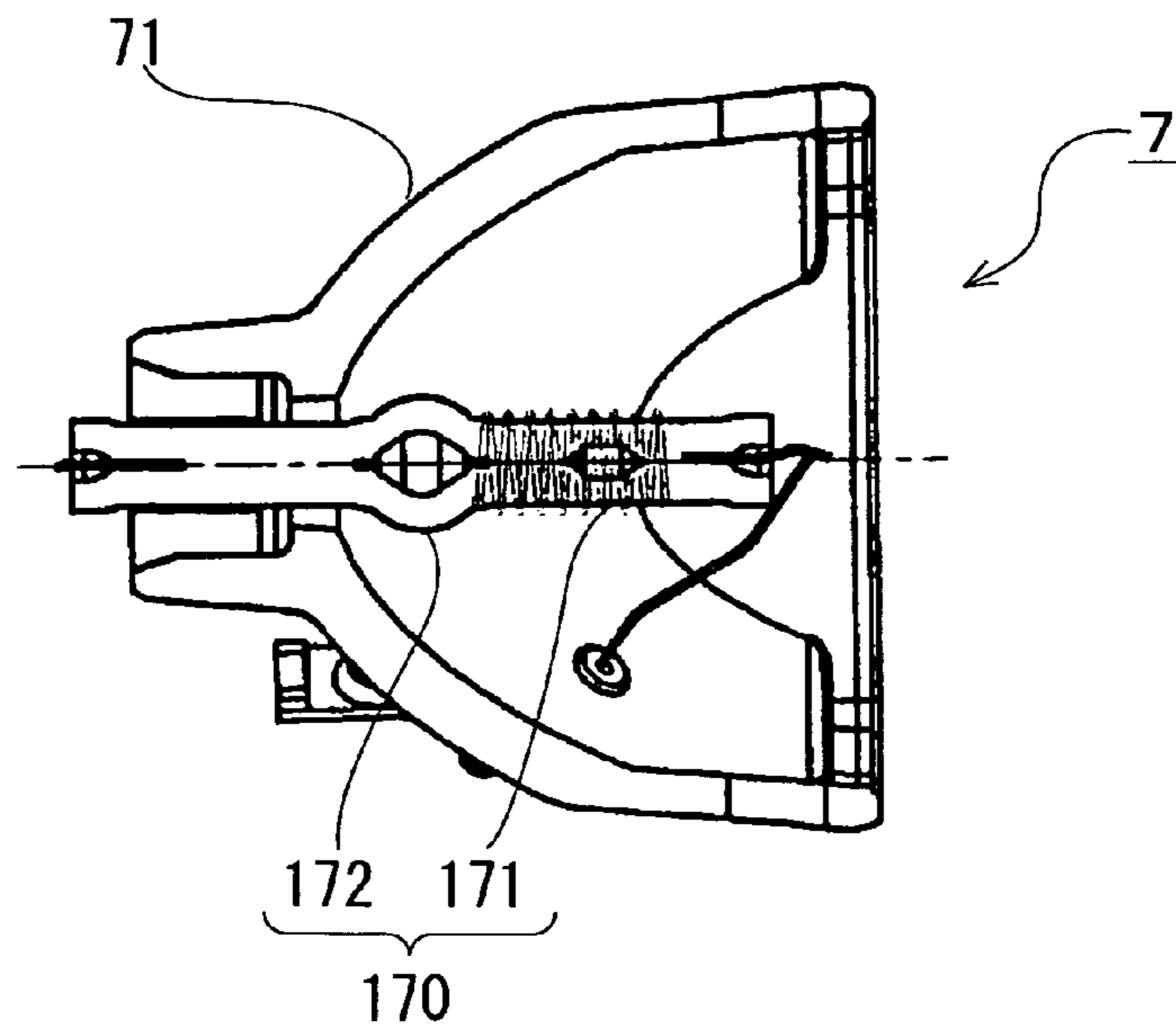


FIG. 35



FIG. 36

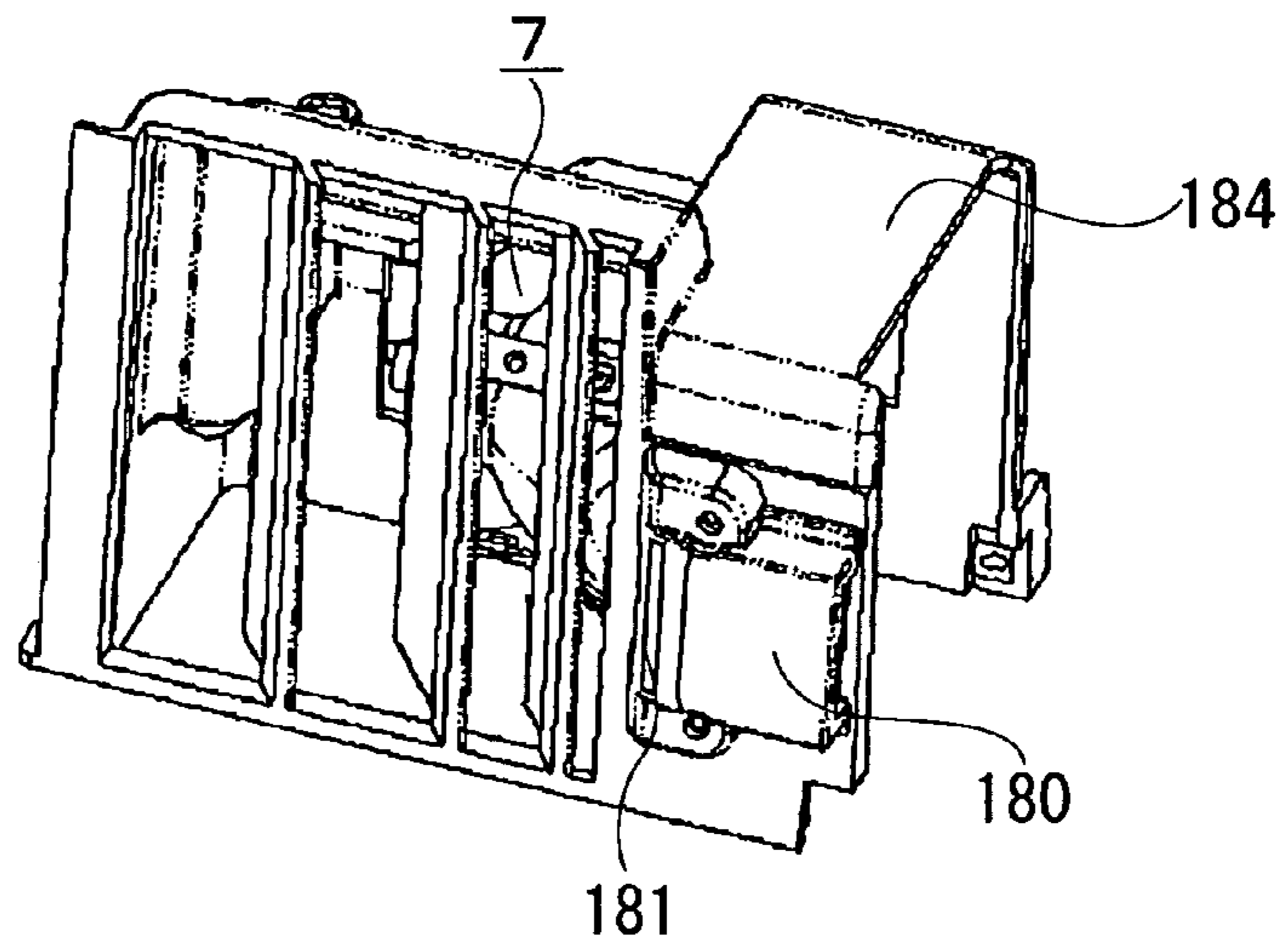


FIG. 37

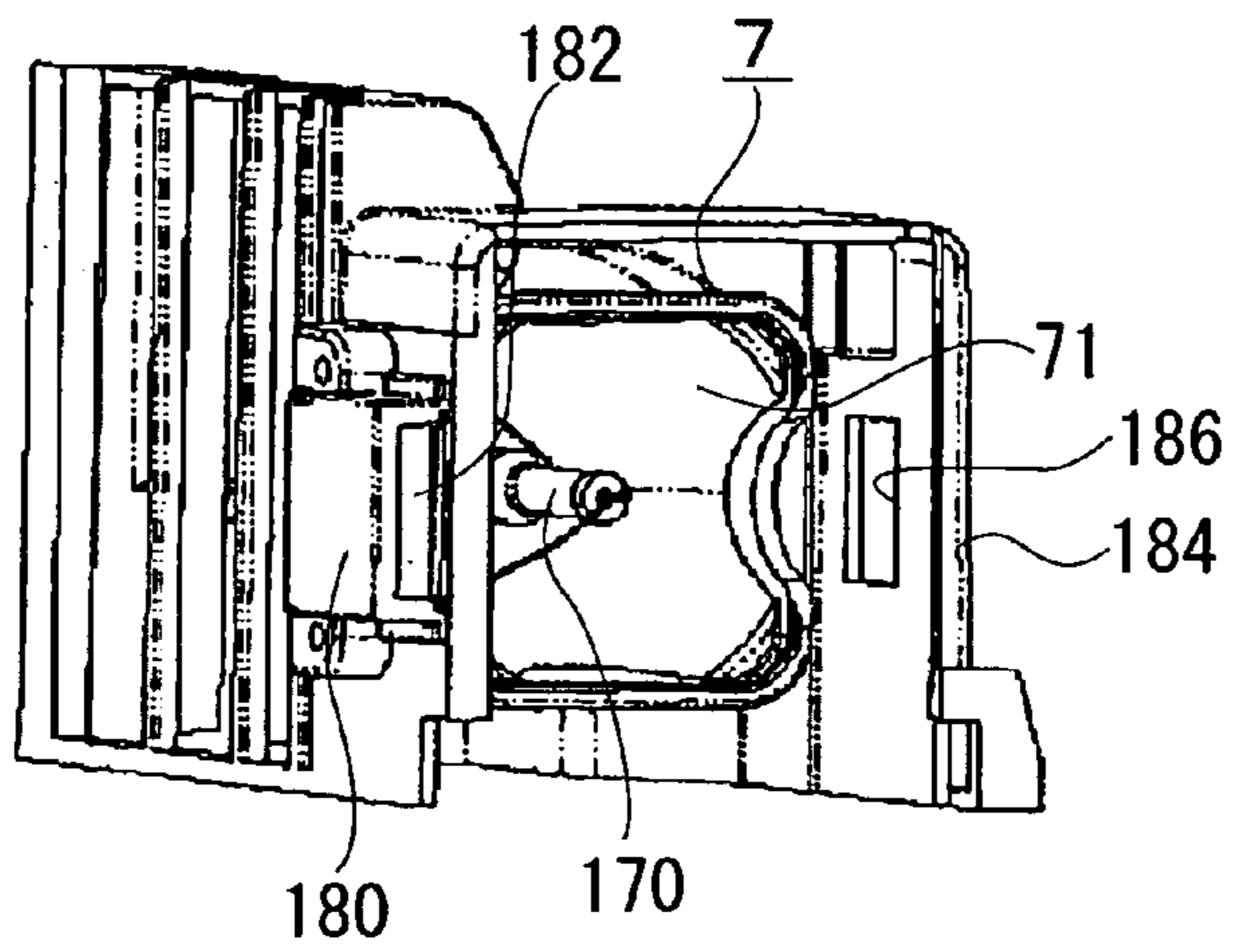


FIG. 38

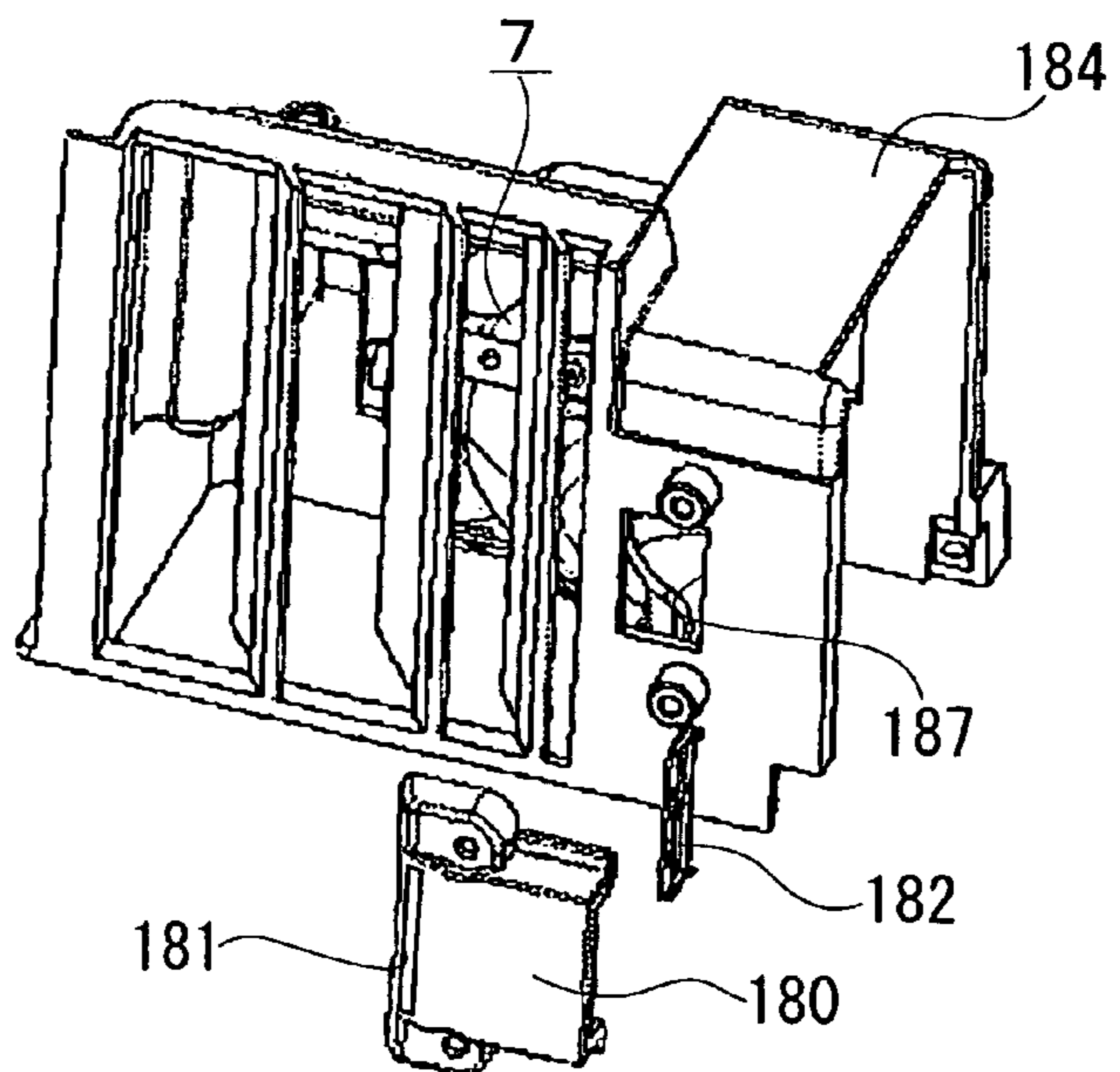
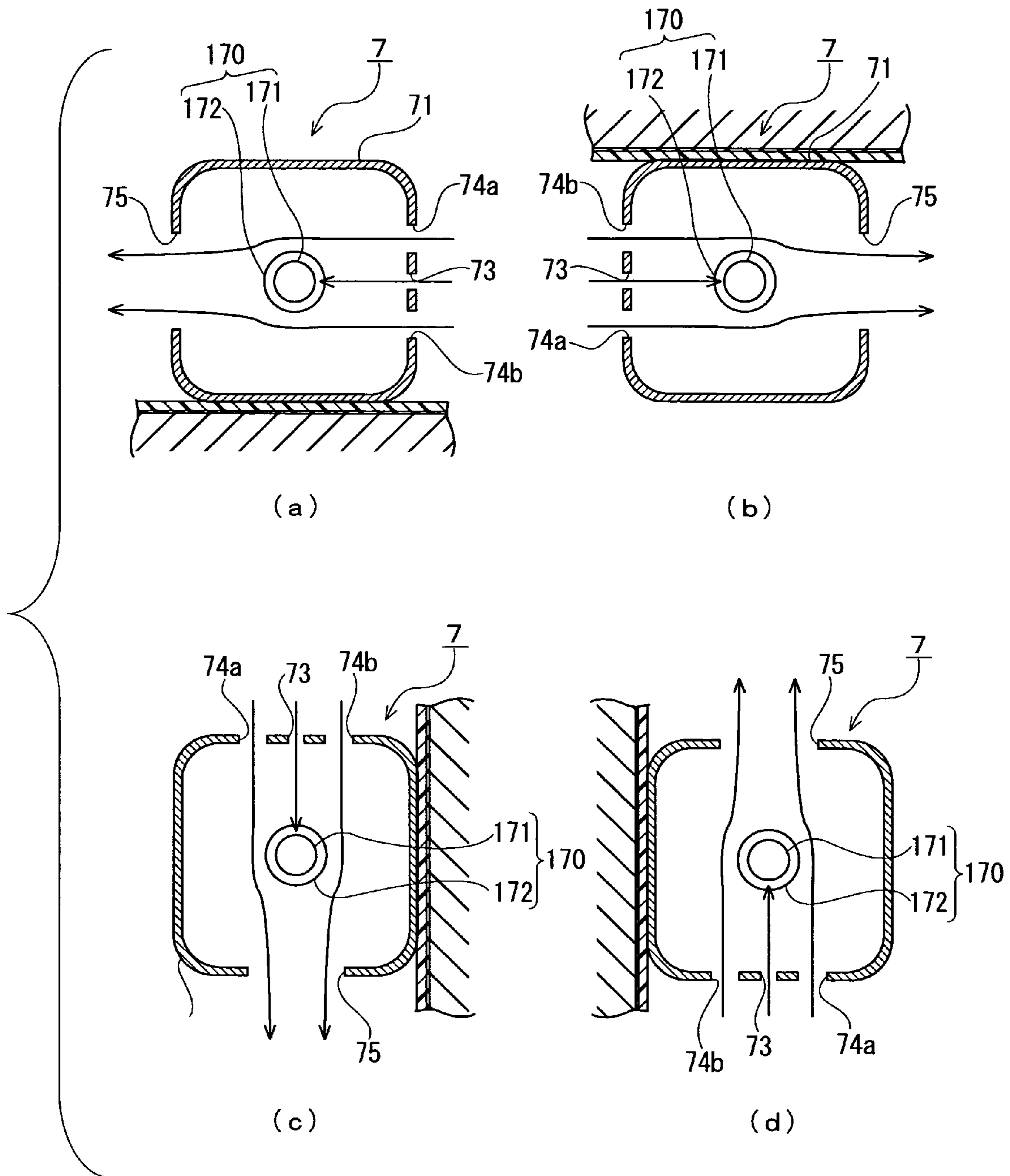


FIG. 39



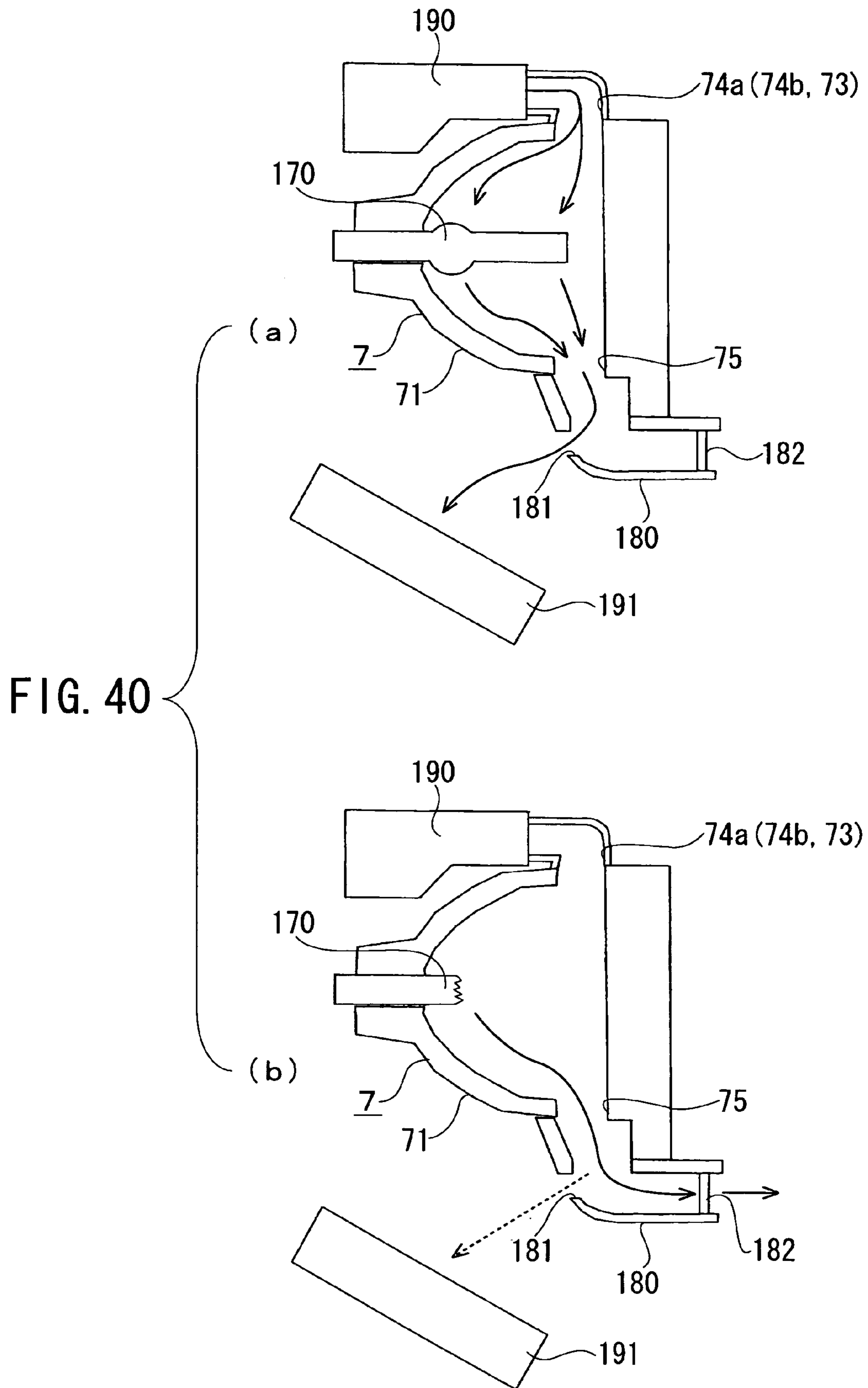




FIG. 41

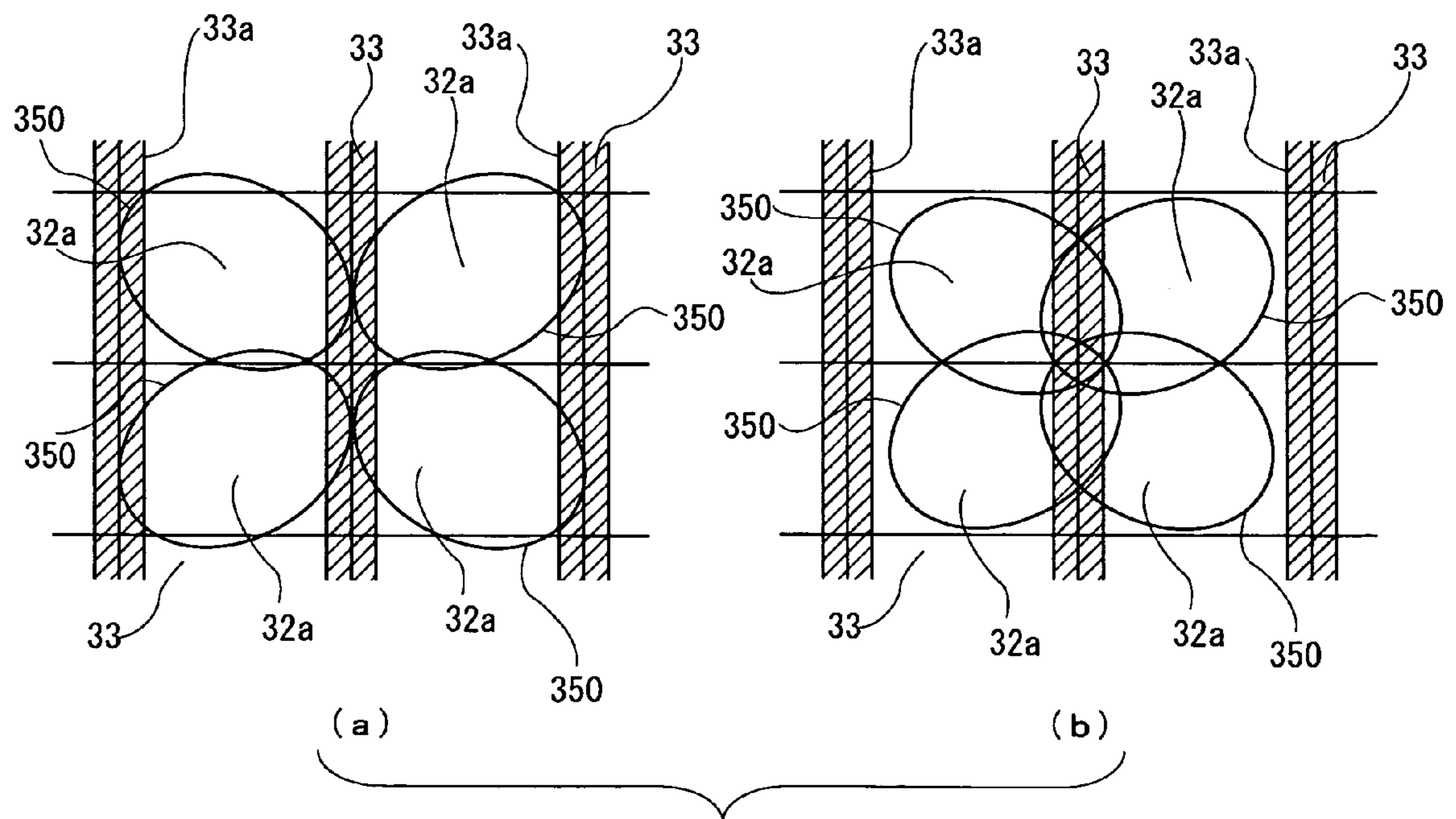
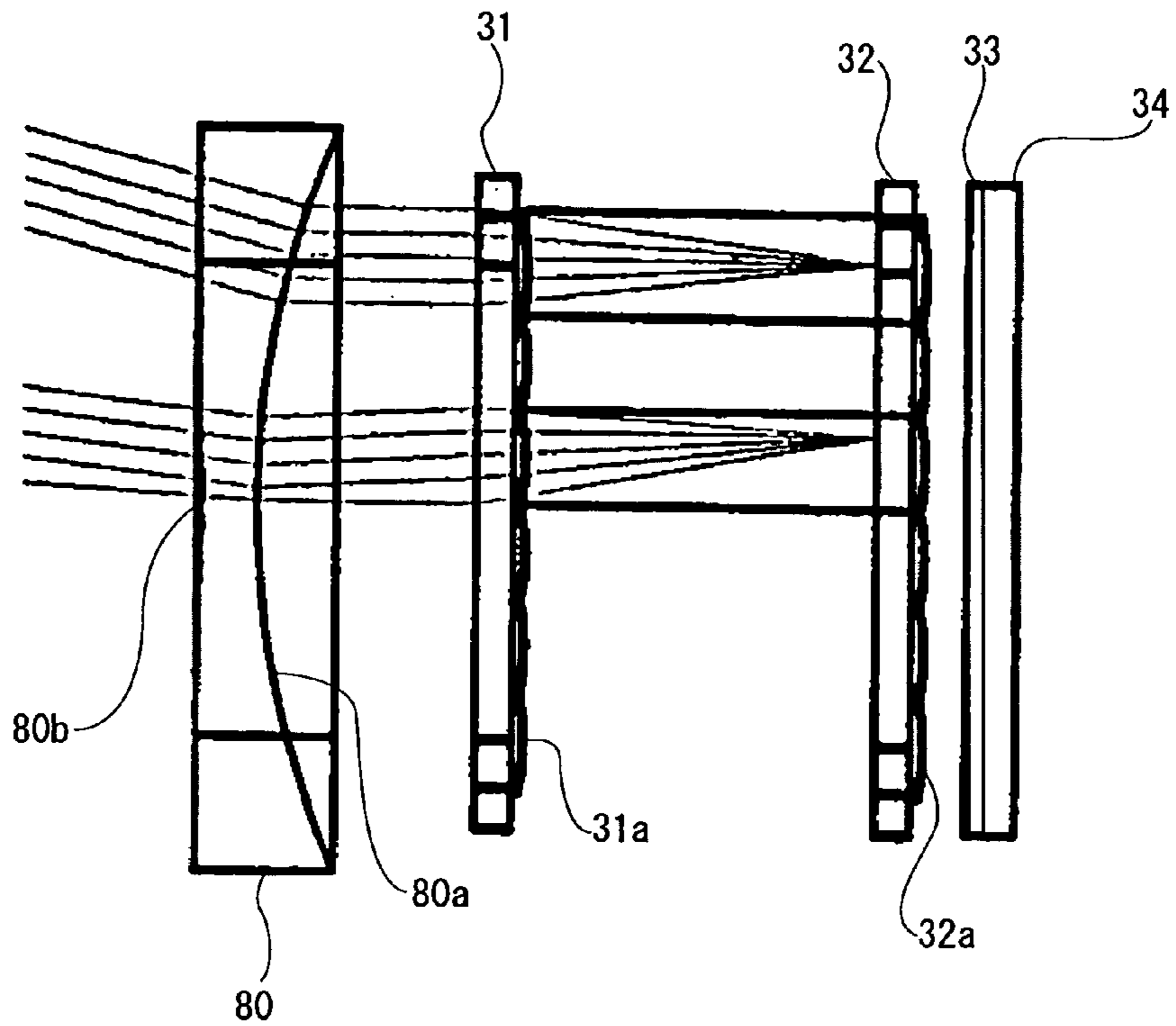


FIG. 42

FIG. 43

(a)

(b)

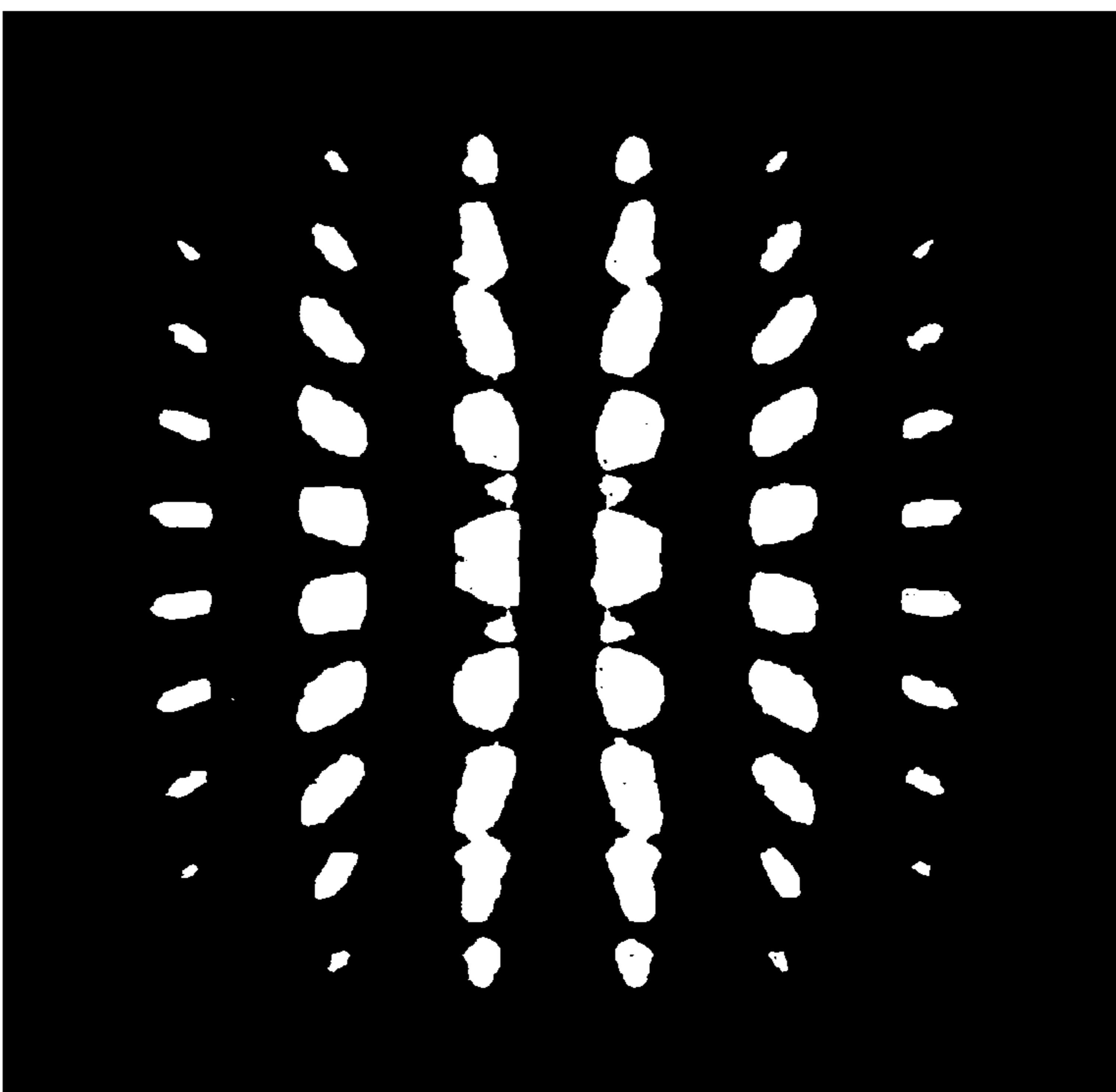
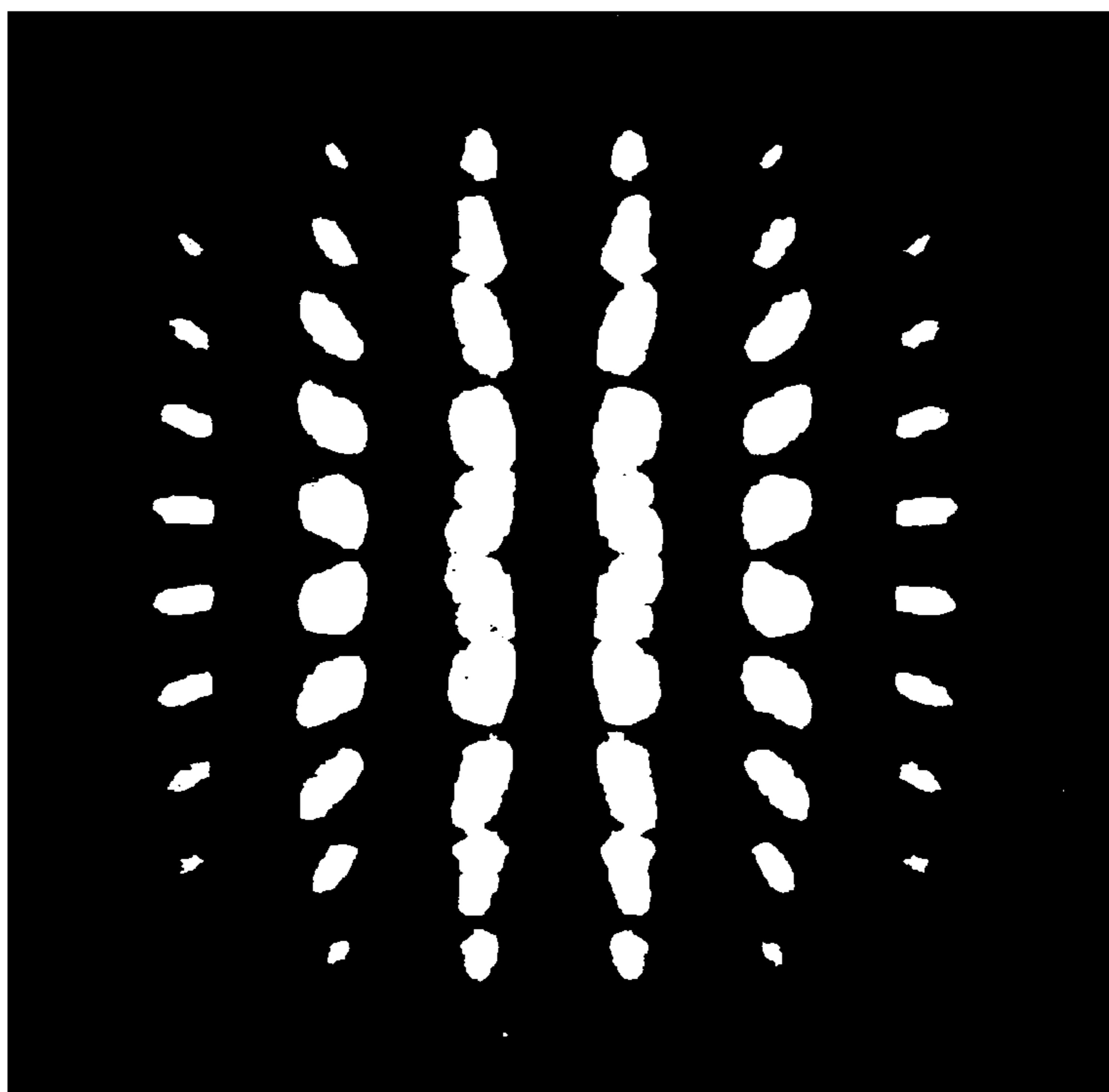


FIG. 44

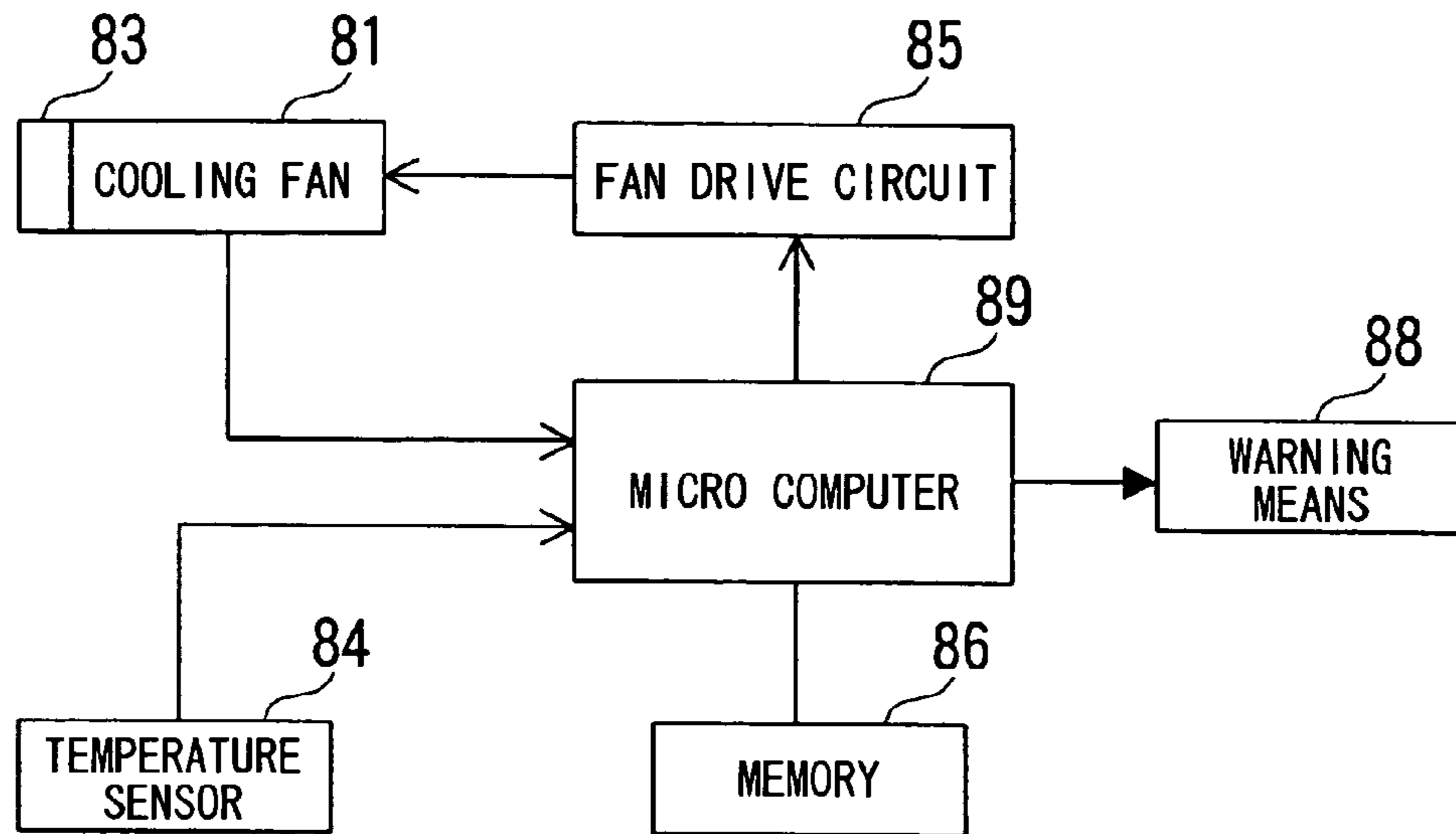


FIG. 45

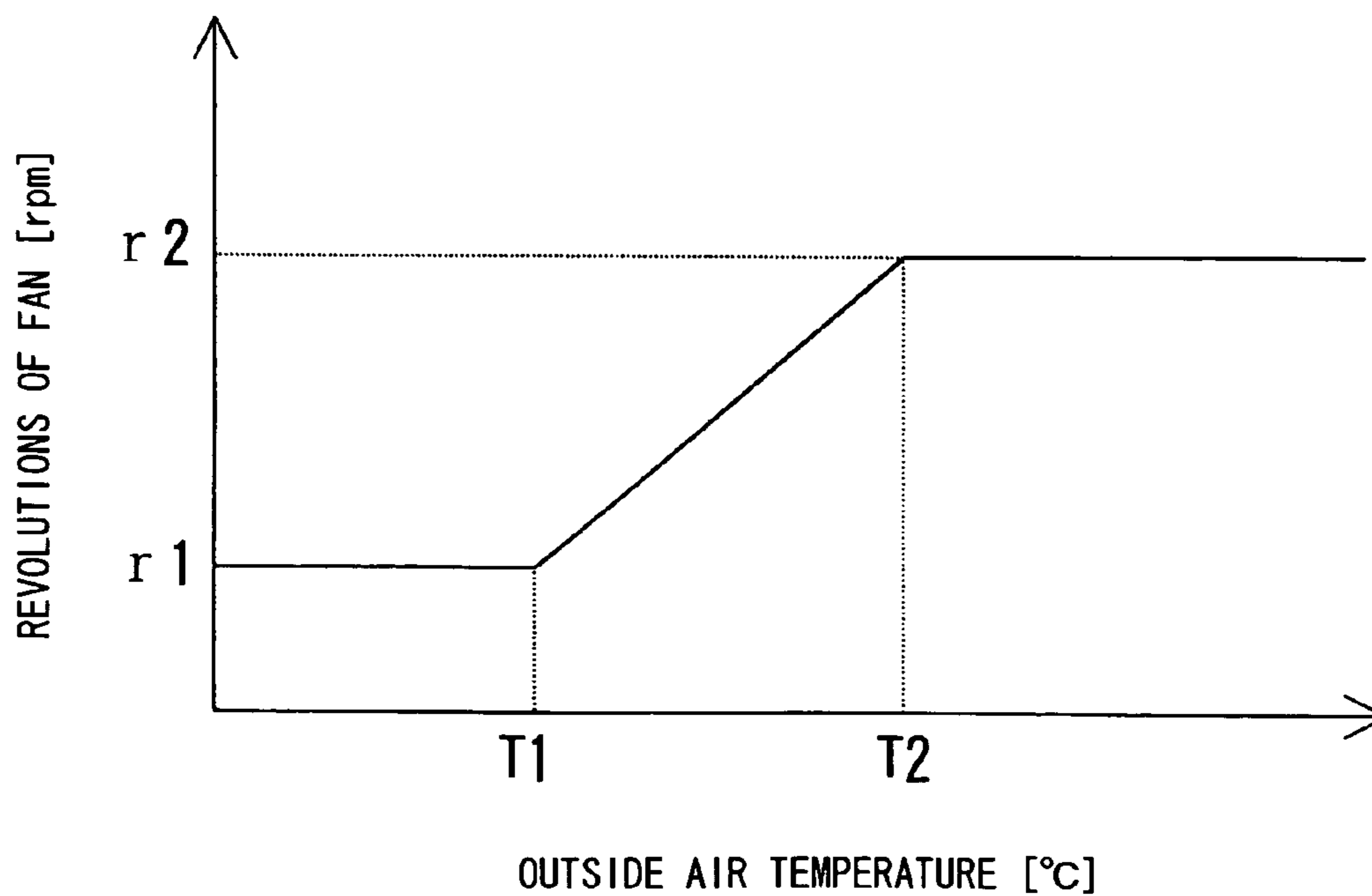


FIG. 46

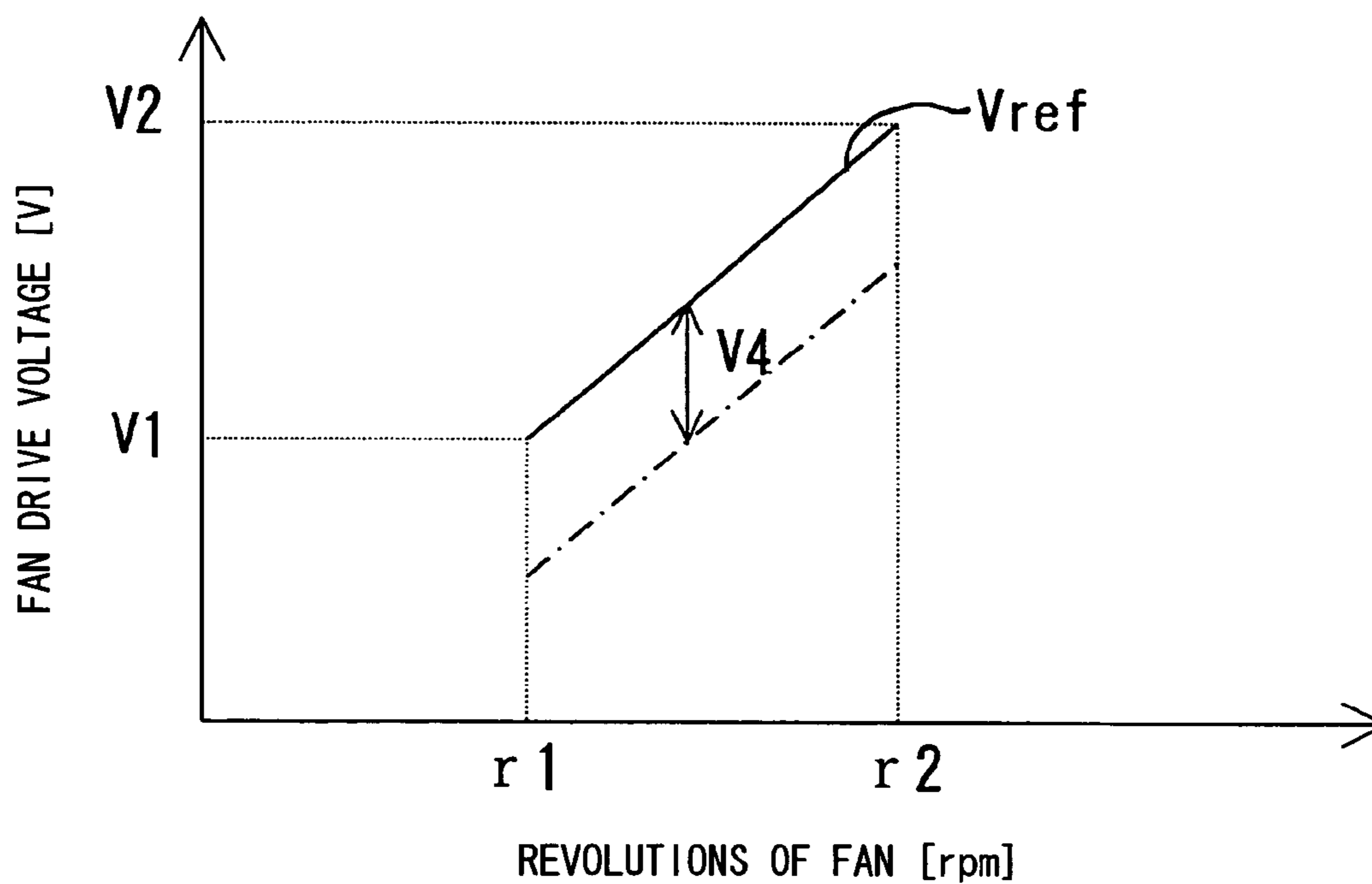
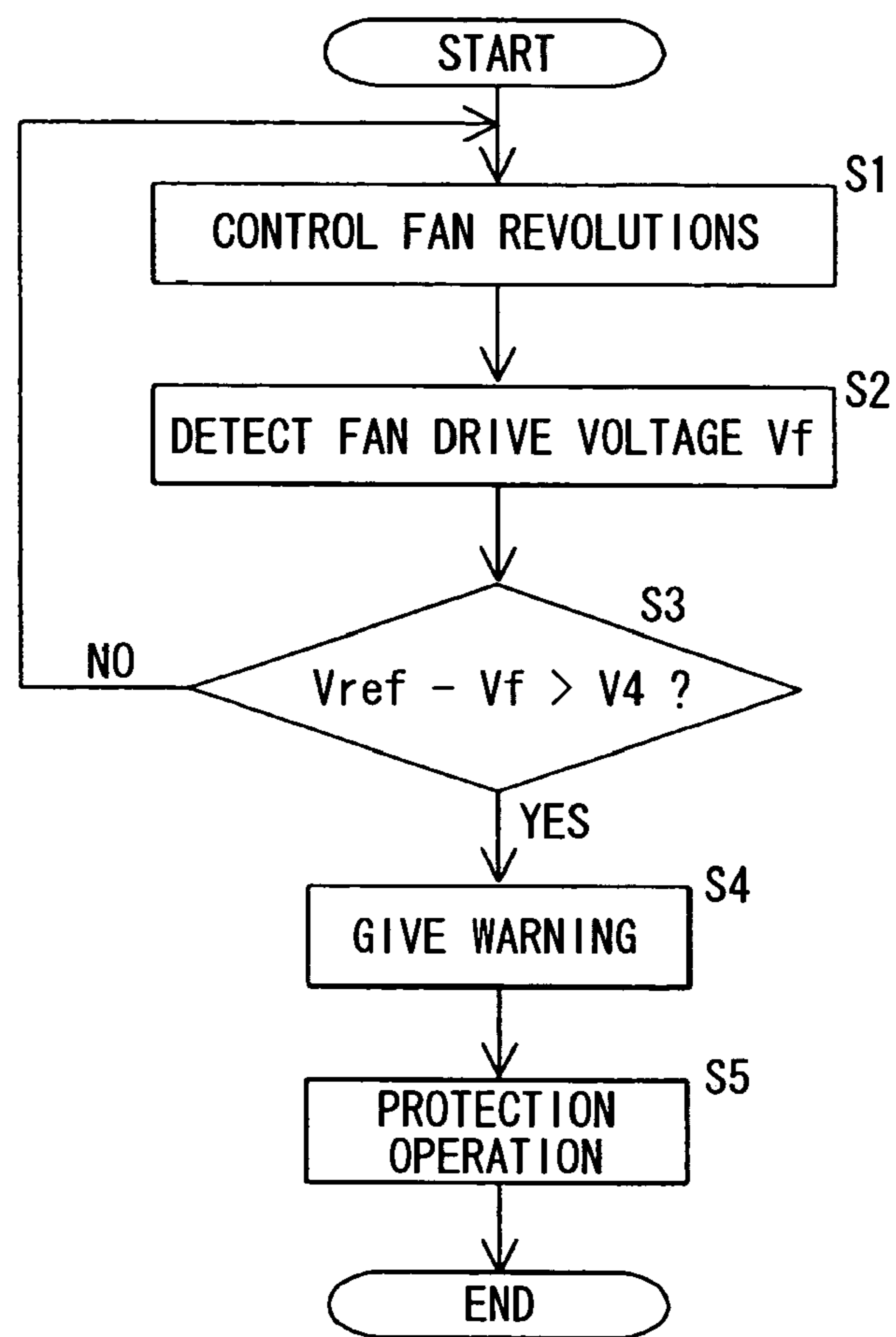




FIG. 47



## 1

## PROJECTOR DEVICE

The priority application Number 2005-262887 upon which this patent application is based is hereby incorporated by reference.

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

The present invention relates to a projector device adapted to guide light from a light source to an optical system to generate image light for magnification projection on a forward screen.

## 2. Description of Related Art

A conventional projector device of this type includes a casing having disposed therein a light source and an optical system including a polarization beam splitter, a polarizing plate, liquid crystal panels, a projection lens, etc. A discharge emission lamp unit such as a halogen lamp and a metal halide lamp is used as the light source.

The lamp unit includes a lamp and a reflector for reflecting light emitted from the lamp toward the optical system. The lamp is formed by enclosing a luminous body inside a quartz bulb. The lamp is cooled by a lamp cooling fan because the lamp has a shortened life when the lamp has a temperature exceeding a limit temperature.

It is known that in light emission of the lamp, the temperature at the vertically upper side of the quartz bulb is higher than the temperature at the lower side thereof, which results in the temperature difference between above and below the quartz bulb. This temperature difference between above and below is the greatest at the position where the luminous body is enclosed in the quartz bulb. In order to fully bring out the performance of the lamp, it is necessary to maintain the temperature of the lamp below the limit temperature, as well as to cool the lamp such that the temperature difference between above and below is held within a certain range.

Accordingly, there has been known a projector device having an air introduction opening for introducing air drawn from the lamp cooling fan into the lamp unit, which is provided at the vertically upper side of the lamp unit such that the air hits the vertically upper side of the quartz bulb (see JP 7-281296, A).

However, if the above projector device is set by being hung from a ceiling, then the setting of the device will be vertically reversed. Consequently, the air introduced from the air introduction opening will hit the vertically lower side of the quartz bulb.

In this case, the vertically lower side of the quartz bulb is excessively cooled, which results in an increased temperature difference between the vertically upper and lower sides of the quartz bulb. Therefore, there has been a problem in that the above projector device cannot be set by being hung from a ceiling.

## SUMMARY OF THE INVENTION

An object of the present invention is to provide a projector device in which the cooling effect for the vertically upper side of a lamp and the cooling effect for the vertically lower side of the lamp are approximately constant regardless of the setting of the device.

A projector device of the present invention includes a lamp unit 7 providing a light source, a cooling fan 190 for cooling the lamp unit 7, and an optical system for generating color image light with the lamp unit 7 providing the light source, the lamp unit 7 including a columnar lamp bulb 170 having a

## 2

luminous body enclosed therein, and a reflector 71 for reflecting light emitted from the lamp bulb 170 toward the optical system, and is capable of taking a plurality of set postures including a first set posture where the lamp bulb 170 of the lamp unit 7 extends approximately horizontally, and a second set posture where the lamp unit 7 is rotated on the lamp bulb 170 by 90 degrees from the first set posture.

A first air introduction opening 74a and a second air introduction opening 74b are provided in a side wall of the lamp unit 7 opposed to the cooling fan 190 and at opposite sides of a plane including a central axis of the lamp bulb 170 and perpendicular to the side wall, and air discharged from the cooling fan 190 is blown to the lamp bulb 170 through the both air introduction openings 74a, 74b.

When the above projector device of the present invention is set in the first set posture, that is, when the projector device is set on a horizontal table, the air drawn from the lamp cooling fan 190 is forcibly separated by part of the side wall of the lamp unit 7 intervening between the first air introduction opening 74a and second air introduction opening 74b, so that the air introduced from the first air introduction opening 74a will flow above the lamp bulb 170, and the air introduced from the second air introduction opening 74b will flow below the lamp bulb 170.

On the other hand, when the projector device is set in the second set posture, that is, when set by being attached to a vertical wall opposed to a screen, the air drawn from the lamp cooling fan 190 is forcibly separated by part of the side wall of the lamp unit 7 intervening between the first air introduction opening 74a and second air introduction opening 74b, so that the air introduced from the first air introduction opening 74a and second air introduction opening 74b will flow through both right and left sides of a light emitting portion 172 of the lamp bulb 170.

Therefore, the air drawn from the lamp cooling fan 190 will not be vertically blown to the vertically lower surface of the lamp bulb 170 in any of the above set postures. This prevents the low-temperature, vertically lower side of the light emitting portion 172 of the lamp bulb 170 from being excessively cooled. Consequently, the temperature difference between the vertically upper side and vertically lower side of the lamp bulb 170 can be held within a certain range regardless of the setting of the device.

In a specific configuration, the first air introduction opening 74a and the second air introduction opening 74b are open toward the light emitting portion 172 of the lamp bulb 170 having the luminous body enclosed therein, and a third air introduction opening 73 open toward an end of the lamp bulb 170 is provided between the first and second air introduction openings 74a, 74b in the side wall of the lamp unit 7.

The specific configuration not only allows the highest-temperature light emitting portion 172 of the lamp bulb 170 to be cooled by the air introduced from the first and second air introduction openings 74a, 74b, but also enables the end of the lamp bulb 170 to be cooled by the air introduced from the third air introduction opening 73.

As described above, according to the projector device of the present invention, the cooling effect for the vertically upper side of the lamp and the cooling effect for the vertically lower side of the lamp are approximately constant regardless of the setting of the device.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a liquid crystal projector device of the present invention;



## 3

FIG. 2 is an exploded perspective view of the liquid crystal projector device;

FIG. 3 is a perspective view showing the liquid crystal projector device with an upper half case thereof removed therefrom;

FIG. 4 is an exploded perspective view of a cooling unit;

FIG. 5 illustrates an optical system and an image synthesizer;

FIG. 6 is a perspective view of a diaphragm mechanism;

FIG. 7 is an exploded perspective view of the diaphragm mechanism;

FIG. 8 includes state transition diagrams of the diaphragm mechanism;

FIG. 9 illustrates areas of light irradiated on a second integrator lens when the diaphragm mechanism is set in respective states shown in FIG. 8;

FIG. 10 illustrates luminous flux blocking states of the diaphragm mechanism;

FIG. 11 is a perspective view of an optical compensation sheet holder;

FIG. 12 is an exploded perspective view of the optical compensation sheet holder;

FIG. 13 illustrates changes in an attachment posture of the optical compensation sheet holder in the case of adjusting the attachment posture of the optical compensation sheet holder with a first adjustment operation;

FIG. 14 illustrates changes in an attachment posture of the optical compensation sheet holder in the case of adjusting the attachment posture of the optical compensation sheet holder with a second adjustment operation;

FIG. 15 is a front view showing a horizontal moving range of a lens shift mechanism;

FIG. 16 is a front view showing a vertical moving range of the lens shift mechanism;

FIG. 17 is an exploded perspective view of the lens shift mechanism;

FIG. 18 is an exploded perspective view enlargingly showing a cylinder, a vertical drive mechanism and a horizontal drive mechanism shown in FIG. 17;

FIG. 19 is an exploded perspective view enlargingly showing a stationary base and a movable member shown in FIG. 17;

FIG. 20 is a perspective view showing a lock mechanism of the lens shift mechanism;

FIG. 21 is a side view showing the lock mechanism;

FIG. 22 illustrates the vertical drive mechanism locked or unlocked by the lock mechanism;

FIG. 23 illustrates the horizontal drive mechanism locked or unlocked by the lock mechanism;

FIG. 24 illustrates a change of how a click-feeling generation mechanism is engaged with the horizontal drive mechanism;

FIG. 25 illustrates a change of how a click-feeling generation mechanism is engaged with the vertical drive mechanism;

FIG. 26 is a perspective view of a lamp unit;

FIG. 27 is an exploded perspective view showing a frame and a concave lens of the lamp unit;

FIG. 28 is a perspective view showing the lamp unit attached to the left end of an optical system holding case;

FIG. 29 is a perspective view showing an attachment structure for attaching the lamp unit to the left end of the optical system holding case;

FIG. 30 is a perspective view showing an attachment structure for attaching a flat spring member to the left end of the optical system holding case;

## 4

FIG. 31 is a sectional view showing the lamp unit attached to the left end of the optical system holding case;

FIG. 32 illustrates fitting pins of the lamp unit having ends thereof inserted into positioning holes, and the lamp unit attached to the left end of the optical system holding case;

FIG. 33 includes enlarged sectional views showing deformations of the flat spring member in the state where the fitting pins of the lamp unit have the ends inserted into the positioning holes, and in the state where the lamp unit is attached to the left end of the optical system holding case;

FIG. 34 is a sectional view showing an internal structure of the lamp unit;

FIG. 35 includes front and back perspective views of the concave lens;

FIG. 36 is a perspective view showing an attached channel housing;

FIG. 37 is a perspective view showing an attached air filter;

FIG. 38 is an exploded perspective view showing an attachment structure of the channel housing and air filter;

FIG. 39 illustrates flows of cooled air in the lamp unit in the state where the liquid crystal projector device of the present invention is set in four different setting postures;

FIG. 40 illustrates a flow of cooled air in the lamp unit in ordinary use, and a flow of air in the lamp unit in a lamp bulb explosion;

FIG. 41 illustrates light paths through the concave lens, first integrator lens, second integrator lens and a slit plate to a polarization beam splitter;

FIG. 42 illustrates arc images formed on a plurality of cells constituting the central portion of the second integrator lens in the case of using the concave lens of the present invention, and arc images formed on a plurality of cells constituting the central portion of the second integrator lens in the case of using a conventional concave lens;

FIG. 43 illustrates arc images formed on the polarization beam splitter in the case of using the concave lens of the present invention, and arc images formed on the polarization beam splitter in the case of using a conventional concave lens;

FIG. 44 is a control block diagram showing a configuration for detecting clogging of an air filter;

FIG. 45 is a graph showing a relationship between outside air temperatures and revolutions of a cooling fan;

FIG. 46 is a graph showing a relationship between revolutions of the cooling fan and reference drive voltages  $V_{ref}$ , and a relationship between revolutions of the cooling fan and drive voltages where it is determined that the air filter is clogged; and

FIG. 47 is a flow chart showing a control procedure to be performed by a microcomputer in detecting clogging of the air filter.

## DETAILED DESCRIPTION OF THE INVENTION

The present invention embodied in a liquid crystal projector device will be specifically described below with reference to the drawings. In the description given below, the image projection direction of the liquid crystal projector device shown in FIG. 1 is defined as the forward direction, and right and left are defined by facing the front face of the liquid crystal projector device.

## Overall Construction

As shown in FIG. 1, the liquid crystal projector device of the present invention includes a flat casing 1 including an upper half case 11 and a lower half case 12. The casing 1 has a surface thereof provided with an operation portion 13 including a plurality of operation buttons and a warning por-



## 5

tion 15 including a plurality of warning lights, while the casing 1 has a front face thereof provided with a projection window 14. The projection window 14 has a projection lens 20 exposed therefrom.

As shown in FIG. 2, the casing 1 has an interior provided with a synthetic resin optical system holding case 30 extending in an approximate L-shape. The optical system holding case 30 has a lamp unit 7 providing a light source attached to the left end thereof. Also attached to the forward end of the optical system holding case 30 is a lens shift mechanism 2 for horizontally and vertically reciprocatingly moving a projection lens system including the projection lens 20 and a cylinder 21 for holding the projection lens 20.

Exposed to the right side wall of the casing 1 are, as shown in FIG. 1, a horizontal operation dial 24 for horizontally reciprocatingly moving the projection lens system, a vertical operation dial 28 for vertically reciprocatingly moving the projection lens system, and a knob 134 of a lever member 133 for fixing the projection lens system in a desired position.

As shown in FIG. 3, the optical system holding case 30 has a slit opening 320 provided at the left end thereof. Inserted in the opening 320 is a diaphragm system 5 for regulating the amount of light to be incident on liquid crystal panels for respective colors 43b, 43g, 43r depending on input data for a projection image in order to improve a contrast of the projection image.

A lamp cooling fan 190 for cooling the lamp unit 7 is placed between the rear wall of the lower half case 12 and one side wall of the lamp unit 7 opposed thereto. An exhaust fan 191 is placed in the left middle of the lower half case 12, with an inlet direction thereof toward the lamp unit 7.

Disposed inside the optical system holding case 30 are an optical system 3 for separating white light emitted from the lamp unit 7 into light of three primary colors, and an image synthesizer 4 for irradiating the liquid crystal panels for three primary colors 43b, 43g, 43r with the light of three primary colors to generate image light of three primary colors, and synthesizing the generated image light of three primary colors into color image light.

The image synthesizer 4 includes a cube-like color synthesis prism 40 having the liquid crystal panel for blue 43b, liquid crystal panel for green 43g and liquid crystal panel for red 43r attached to three respective side surfaces thereof. The three liquid crystal panels 43b, 43g, 43r have light incidence sides thereof provided with optical compensation sheet holders 6b, 6g, 6r, respectively. The optical compensation sheet holders 6b, 6g, 6r hold three optical compensation sheets (not shown) for blocking incidence of unwanted component waves of light on the respective liquid crystal panels 43b, 43g, 43r. Disposed below the image synthesizer 4 is, as shown in FIG. 4, a cooling system 8 for cooling a plurality of optical components constituting the image synthesizer 4.

The liquid crystal projector device of the present invention will be described below in detail in construction with reference to the drawings.

### Optical System 3

As shown in FIG. 5, the white light from the lamp unit 7 is guided through a first integrator lens 31, the diaphragm mechanism 5, a second integrator lens 32, a slit plate 33, a polarization beam splitter 34 and a field lens 35 to a first dichroic mirror 36.

The first integrator lens 31 and second integrator lens 32 are made of a heat-resistant glass fly-eye lens as shown in FIG. 9, and have a function of uniformizing illuminance distribution of the white light emitted from the lamp unit 7. The slit plate 33 is made of an aluminum thin plate, and has a

## 6

function of blocking unwanted incident light toward the polarization beam splitter 34. The polarization beam splitter 34 has a function of extracting only one component wave out of P- and S-waves of light.

The light having passed through the polarization beam splitter 34 shown in FIG. 5 reaches through the field lens 35 to the first dichroic mirror 36. The first dichroic mirror 36 has a function of reflecting only a blue component of light and passing red and green components therethrough. A second dichroic mirror 37 has a function of reflecting the green component of light and passing the red component therethrough, and a field mirror 38a has a function of reflecting the red component. Thus, the white light emitted from the lamp unit 7 is separated by the first and second dichroic mirrors 36, 37 into blue light, green light and red light, and guided to the image synthesizer 4.

### Image Synthesizer 4

As shown in FIG. 5, the image synthesizer 4 includes the cube-like color synthesis prism 40 having the liquid crystal panel for blue 43b, liquid crystal panel for green 43g and liquid crystal panel for red 43r attached to the three respective side surfaces thereof.

As shown in FIG. 3, the optical compensation sheet holders 6b, 6g, 6r are attached to the light incidence sides of the three liquid crystal panels 43b, 43g, 43r, respectively. The optical compensation sheet holders 6b, 6g, 6r hold the three optical compensation sheets 42b, 42g, 42r for blocking incidence of unwanted component waves of light on the respective liquid crystal panels 43b, 43g, 43r.

The blue light reflected by the first dichroic mirror 36 and a field mirror 38c shown in FIG. 5 is guided by an incidence polarizing plate for blue 41b through the incidence polarizing plate for blue 41b, the optical compensation sheet for blue 42b, the liquid crystal panel for blue 43b and an emergence polarizing plate for blue 44b to the color synthesis prism 40.

The green light reflected by the second dichroic mirror 37 is guided by an incidence polarizing plate for green 41g through the incidence polarizing plate for green 41g, the optical compensation sheet for green 42g, the liquid crystal panel for green 43g and an emergence polarizing plate for green 44g to the color synthesis prism 40.

Similarly, the red light transmitted by the first dichroic mirror 36 and second dichroic mirror 37 and reflected by two field mirrors 38a, 38b is guided by an incidence polarizing plate for red 41r of the image synthesizer 4 through the incidence polarizing plate for red 41r, the optical compensation sheet for red 42r, the liquid crystal panel for red 43r and an emergence polarizing plate for red 44r to the color synthesis prism 40.

The image light of the three colors guided to the color synthesis prism 40 is synthesized by the color synthesis prism 40, and the resulting color image light is to be magnifyingly projected through the projection lens 20 on a forward screen.

### Diaphragm Mechanism 5

As shown in FIG. 5, the diaphragm mechanism 5 is arranged between the first integrator lens 31 and second integrator lens 32 constituting the optical system 3. As shown in FIG. 3, the diaphragm mechanism 5 is attached to the optical system holding case 30, while inserted in the slit opening 320 provided at the left end of the optical system holding case 30.

The diaphragm system 5 is for regulating the amount of light to be incident on the liquid crystal panels for the respective colors 43b, 43g, 43r depending on input data for an image to be projected to thereby improve a contrast of the projection image. For example, when input data for an image to be projected concentrates in a low brightness region, that is,



when the image to be projected is a generally dark image, the diaphragm mechanism **5** partly blocks the light emitted from the lamp unit **7** to set a smaller than usually amount of light to be incident on the liquid crystal panels for the respective colors **43b**, **43g**, **43r**, while a correction is made to the input data to expand a dynamic range. This can improve a contrast of the projection image.

Of the light having passed through the second integrator lens **32** to reach the liquid crystal panels for the respective colors **43b**, **43g**, **43r**, light having peripherally passed through the second integrator lens **32** often causes light leak because it would be incident slantingly relative to a surface of each of the liquid crystal panels **43b**, **43g**, **43r** compared with light having centrally passed through the second integrator lens **32**. Accordingly, the diaphragm mechanism **5** blocks light to be peripherally incident on the second integrator lens **32** to thereby prevent light leak from occurring in the liquid crystal panels for the respective colors **43b**, **43g**, **43r**, which improves a contrast of the projection image.

As shown in FIG. **6** and FIG. **7**, the diaphragm mechanism **5** includes a T-shaped first diaphragm plate **53** and an L-shaped second diaphragm plate **54** superposed on each other on a plane perpendicular to the optical axis of light passing through the diaphragm mechanism **5**, which are disposed inside a flat casing **50** formed by joining a rectangular base plate **51** and a cover plate **52** to each other. Attached to the cover plate **52** is a motor **55** for driving the first diaphragm plate **53** and second diaphragm plate **54** toward or away from each other along the plane.

The base plate **51** and cover plate **52** have rectangular openings **51a**, **52a**, respectively, formed therein. The light having passed through the first integrator lens **31** shown in FIG. **5** irradiates the second integrator lens **32** through the both openings **51a**, **52a**.

As shown in FIG. **6**, the motor **55** has a turning member **56** attached to an output shaft thereof, which rotates together with the output shaft. The turning member **56** has opposite ends thereof formed with projections **56a**, **56a** toward the cover plate **52**. The projections **56a**, **56a** are engaged with a pair of circular arc grooves **51b**, **51b**, **52b**, **52b** provided in the base plate **51** and cover plate **52**, respectively, shown in FIG. **7**. As shown in FIG. **7**, the first diaphragm plate **53** and second diaphragm plate **54** have left ends thereof provided with rectangular through holes **53a**, **54a**. The projections **56a**, **56a** of the turning member **56** are through both through holes **53a**, **54a**, respectively.

The first diaphragm plate **53** and second diaphragm plate **54** have an upper end thereof and a lower end thereof provided with two guide holes **53b**, **53b**, **54b**, **54b**, respectively, along a pair of long sides constituting a rectangular contour of the diaphragm mechanism **5** shown in FIG. **6**, while the base plate **51** has, along each of the pair of long sides, two guide pins **51c**, **51c**, **51d**, **51d**, four in total, protruded from an inner surface thereof toward the cover plate **52**. The two upper guide pins **51c**, **51c** are engaged with the two guide holes **53b**, **53b** of the first diaphragm plate **53**, respectively. The two lower guide pins **51d**, **51d** are engaged with the two guide holes **54b**, **54b** of the second diaphragm plate **54**, respectively.

As shown in FIG. **9**, the second integrator lens **32** includes **56** rectangular cells **32a** arranged in the form of a matrix. The first integrator lens **31** also has the same arrangement as of the second integrator lens **32**. As shown in FIGS. **10(a)-(c)**, the second integrator lens **32** is arranged such that optical centers of the cells **32a** constituting the second integrator lens **32** correspond to focuses of respective cells **31a** constituting the first integrator lens **31**.

Therefore, as shown in FIGS. **10(a)-(c)**, the cells **31a** of the first integrator lens **31** emit quadrangular-pyramid-shaped luminous fluxes **300** toward the optical centers of the corresponding cells **32a** of the second integrator lens **32**. Each of the luminous fluxes **300** has a rectangular cross-sectional shape at the set position of the diaphragm mechanism **5**.

As shown in FIG. **7**, the first diaphragm plate **53** and second diaphragm plate **54** have recesses **53c**, **54c**, respectively, formed on opposed end faces thereof. Both recesses **53c**, **54c** are each formed in the shape of stairs along latticed border lines between a plurality of luminous fluxes **300** from respective cells **31a** of the first integrator lens **31** to respective cells **32a** of the second integrator lens **32**.

As shown in FIGS. **8(a)-(e)**, the recesses **53c**, **54c** of both diaphragm plates **53**, **54** are exposed from the openings **51a**, **52a** in accordance with slide operation of both diaphragm plates **53**, **54**. The light having passed through the first integrator lens **31** reaches the second integrator lens **32** through a light passage window **57** surrounded by both recesses **53c**, **54c**.

FIGS. **8(a)-(e)** show states where the recesses **53c**, **54c** of both diaphragm plates **53**, **54** have end faces thereof positioned on latticed border lines between a plurality of luminous fluxes **300** from respective cells **31a** of the first integrator lens **31** to respective cells **32a** of the second integrator lens **32** (hereafter referred to as ideal light blocking states).

FIGS. **9(a)-(e)** show areas of light irradiated on the second integrator lens **32** with hatching when the diaphragm mechanism **5** is set in the ideal light blocking states shown in FIGS. **8(a)-(e)**. FIGS. **10(a)-(c)** show that when the diaphragm mechanism **5** is set as shown in FIG. **8(a)**, FIG. **8(c)** and FIG. **8(e)**, respectively, the diaphragm mechanism **5** blocks a plurality of luminous fluxes **300** of all the luminous fluxes **300** from the respective cells **31a** of the first integrator lens **31** to the respective cells **32a** of the second integrator lens **32**.

As shown in FIGS. **8(a)-(e)**, when the motor **55** rotates clockwise, the first diaphragm plate **53** slides rightward, while the second diaphragm plate **54** slides leftward. Consequently, the first diaphragm plate **53** and second diaphragm plate **54** are moved toward each other. This makes larger the area of the first diaphragm plate **53** and second diaphragm plate **54** exposed from the openings **51a**, **52a**.

On the other hand, when the motor **55** rotates counterclockwise, the first diaphragm plate **53** slides leftward, while the second diaphragm plate **54** slides rightward. Consequently, the first diaphragm plate **53** and second diaphragm plate **54** are moved away from each other. This makes smaller the area of the first diaphragm plate **53** and second diaphragm plate **54** exposed from the openings **51a**, **52a**.

As described above, because the area of the first diaphragm plate **53** and the second diaphragm plate **54** exposed from the openings **51a**, **52a** varies depending on the rotation angle of the motor **55**, the light irradiation region on the second integrator lens **32** can be varied by controlling the rotation angle of the motor **55** between the first ideal light blocking state shown in FIG. **8(a)** and the fifth ideal light blocking state shown in FIG. **8(e)**.

In the first ideal light blocking state shown in FIG. **8(a)**, the turning member **56** is turned counterclockwise by the motor **55** to the limit position. In this state, as shown in FIG. **9(a)** and FIG. **10(a)**, all the **56** cells **32a** constituting the second integrator lens **32** are irradiated with light. On the other hand, in the fifth ideal light blocking state shown in FIG. **8(e)**, the turning member **56** is turned clockwise by the motor **55** to the limit position. In this state, as shown in FIG. **9(e)** and FIG. **10(c)**, only four central constituent cells **32a** of the second integrator lens **32** are irradiated with light. In the second ideal



light blocking state shown in FIG. 8(b), as shown in FIG. 9(b), 44 cells 32a except 12 cells 32a arranged peripherally in the second integrator lens 32 are irradiated with light.

Similarly, in the third ideal light blocking state shown in FIG. 8(c), as shown in FIG. 9(c) and FIG. 10(b), only 28 cells 32a generally in the form of a cross arranged centrally of the second integrator lens 32 are irradiated with light. In the fourth ideal light blocking state shown in FIG. 8(d), as shown in FIG. 9(d), only 12 cells 32a generally in the form of a cross arranged centrally of the second integrator lens 32 are irradiated with light.

If the diaphragm mechanism 5 is set in an intermediate state between the first to fifth ideal light blocking states shown in FIGS. 8(a)-(e), that is, if the first diaphragm plate 53 and second diaphragm plate 54 move so as to partly block passage of at least one luminous flux 300 of all the luminous fluxes 300 from the respective cells 31a of the first integrator lens 31 to the respective cells 32a of the second integrator lens 32, and to allow passage thereof in the other part, then uneven coloring can occur in the projection image.

Because the opposed recesses 53c, 54c of both diaphragm plates 53, 54 defining the light passage window 57 that allows passage of light are formed in the shape of stairs along latticed border lines between a plurality of luminous fluxes 300 from respective cells 31a of the first integrator lens 31 toward respective cells 32a of the second integrator lens 32, the diaphragm mechanism 5 of the present invention changes from the intermediate state to any one of the first to fifth ideal light blocking states whenever the end faces of the recesses 53c, 54c of both diaphragm plates 53, 54 reach the latticed border lines during reciprocation of both diaphragm plates 53, 54. Therefore, both diaphragm plates 53, 54 are set in the ideal light blocking state more frequently than conventionally during reciprocation of both diaphragm plates 53, 54. Consequently, occurrence of uneven coloring is suppressed more than conventionally.

In addition, because the recesses 53c, 54c of both diaphragm plates 53, 54 are formed in the shape of stairs along latticed border lines between a plurality of luminous fluxes 300 from respective cells 31a of the first integrator lens 31 to respective cells 32a of the second integrator lens 32, the diaphragm mechanism 5 can be constituted of a one-directional slide mechanism for horizontally moving both diaphragm plates 53, 54 close or away. This allows the more simplified diaphragm mechanism 5 than a conventional one that needs a two-directional slide mechanism.

#### Optical Compensation Sheet Holders 6b, 6g, 6r

As shown in FIG. 3, the optical compensation sheet holders 6b, 6g, 6r are attached to the optical system holding case 30 at three end edges thereof opposed to three side surfaces of the color synthesis prism 40 of the image synthesizer 4. The optical compensation sheet holders 6b, 6g, 6r hold the optical compensation sheets 42b, 42g, 42r, respectively, shown in FIG. 5. As shown in FIG. 5, the optical compensation sheets 42b, 42g, 42r are arranged between the incidence polarizing plates for the respective colors 41b, 41g, 41r and the liquid crystal panels for the respective colors 43b, 43g, 43r, respectively.

The optical compensation sheets 42b, 42g, 42r have liquid crystal molecules therein. The optical compensation sheets 42b, 42g, 42r are attached such that the liquid crystal molecules have a slow axis in a direction parallel to an alignment direction of liquid crystal molecules constituting the respective liquid crystal panels 43b, 43g, 43r to thereby perform a function of blocking incidence of unwanted component waves of light on the respective liquid crystal panels 43b, 43g,

43r. This can prevent light leak and uneven coloring from occurring in the liquid crystal panels 43b, 43g, 43r.

Because the three optical compensation sheet holders 6b, 6g, 6r have the same configuration, only the optical compensation sheet holder for blue 6b will be described below, and the optical compensation sheet holders for green and red 6g, 6r will not be described. As shown in FIG. 11, the optical compensation sheet 42b is held by the optical compensation sheet holder 6b turnably within a plane perpendicular to an optical axis of light (indicated by the dashed line in the drawing) passing through the optical compensation sheet 42b, and turnably on a rotation axis parallel to a plane perpendicular to the optical axis. The attachment posture of the optical compensation sheet 42b can be adjusted by adjusting fastening positions of two screws 64a, 64b, as described later. The attachment posture of each of the optical compensation sheets 42b, 42g, 42r is adjusted in an adjustment process before shipment of the liquid crystal projector device.

As shown in FIG. 11 and FIG. 12, the optical compensation sheet holder 6b includes a rectangular frame 61 for holding the optical compensation sheet 42b, a turning member 62 for turnably holding the frame 61 and to be attached to the optical system holding case 30, and a slide member 63 to engage with the frame 61.

As shown in FIG. 12, the frame 61 has a pair of columnar shanks 61a, 61a protruded therefrom so as to be approximately parallel to one of two diagonals of the liquid crystal panel for blue 43b, and a stepped projection 61b protruded upward from the upper left corner of the frame 61. The optical compensation sheet 42b is fitted in an opening 61c provided centrally of the frame 61.

The turning member 62 has a rectangular holding part 62a for holding the frame 61, and an attachment part 62b along an upper wall 310 of the optical system holding case 30. The holding part 62a has a rectangular opening 62c provided centrally therein, and a pair of supports 66a, 66b for supporting the shanks 61a, 61a of the frame 61, protruded around the opening 62c, on a line approximately parallel to one of two diagonals of the liquid crystal panel for blue 43b, and in the traveling direction of light passing through the optical compensation sheet 42b. Of the pair of supports 66a, 66b, one support 66a is formed with a through hole through which the shank 61a of the frame 61 penetrates, while the other support 66b is L-shaped. The holding part 62a has a pair of flat springs 67a, 67b formed downward from lower opposite ends thereof, while the holding part 62a has a semicircular recess 65 formed at the lower left end thereof.

The optical system holding case 30 has a side wall 311 having a pair of foot parts 314a, 314b protruded therefrom in the optical axis direction of light to pass through the optical compensation sheet 42b. Both foot parts 314a, 314b are formed with grooves 315a, 315b into which both flat springs 67a, 67b of the holding part 62a are to be inserted. The flat springs 67a, 67b are to be held between opposed surfaces of the grooves 315a, 315b, respectively, with the optical compensation sheet holder 6b attached to the optical system holding case 30. Further, the left groove 315a has a columnar shank 316 formed therein parallel to the optical axis. The recess 65 of the holding part 62a is to be fitted with the shank 316.

The attachment part 62b of the turning member 62 is provided with a screw hole 68 through which a screw 64a for fixing the slide member 63 penetrates, a first long hole 69a through which a screw 64b for fixing the turning member 62 to the upper wall 310 of the optical system holding case 30 penetrates, and a third long hole 69b through which a pair of pins 312a, 312b protruded from the upper wall 310 of the



## 11

optical system holding case 30 penetrate. The pair of pins 312a, 312b are provided away from each other in the right-and-left direction perpendicular to the optical axis of light to pass through the optical compensation sheet 42b. The first long hole 69a and third long hole 69b are shaped to be long in the left-and-right direction.

The slide member 63 has a flat plate part 63a along the attachment part 62b of the turning member 62, and a U-shaped pinching part 63b protruded downward from one corner of the flat plate part 63a. The flat plate part 63a is provided with a second long hole 69c longer in the optical axis direction of light to pass through the optical compensation sheet 42b. The screw 64a for fixing the slide member 63 to the attachment part 62b of the turning member 62 is to penetrate through the second long hole 69c. The pinching part 63b is to pinch the projection 61b of the frame 61.

The optical compensation sheet holder 6b is adjusted in place using a first adjustment operation of turning the optical compensation sheet holder 6b, with the screw 64b loosened, on the shank 316 provided on the left foot part 314a of the optical system holding case 30 within a plane perpendicular to the optical axis of light to pass through the optical compensation sheet 42b, and a second adjustment operation of sliding the slide member 63 of the optical compensation sheet holder 6b, with the screw 64a loosened, along the optical axis direction to thereby turn the frame 61 on the pair of shanks 61a, 61a, so that a surface of the optical compensation sheet 42b is inclined relative to a plane perpendicular to the optical axis.

FIGS. 13(a)-(c) show the optical compensation sheet holder 6b, the attachment posture of which is adjusted by the first adjustment operation.

As shown in FIG. 11, the pair of pins 312a, 312b of the optical system holding case 30 are through the third long hole 69b of the turning member 62 of the optical compensation sheet holder 6b. Therefore, loosening the screw 64b allows slide operation of the optical compensation sheet holder 6b within the first long hole 69a in the left-and-right direction perpendicular to the optical axis of light to pass through the optical compensation sheet 42b.

The recess 65 of the turning member 62 of the optical compensation sheet holder 6b is engaged with the shank 316 provided on the left foot part 314a of the optical system holding case 30. Therefore, as shown in FIGS. 13(a)-(c), the slide operation of the optical compensation sheet holder 6b in the left-and-right direction causes the optical compensation sheet holder 6b to turn about the shank 316 within a plane perpendicular to the optical axis.

FIG. 13(a) shows a state where the screw 64b is fastened at the right end of the first long hole 69a of the optical compensation sheet holder 6b (hereafter referred to as the first fastened state). FIG. 13(c) shows a state where the screw 64b is fastened at the left end of the first long hole 69a of the optical compensation sheet holder 6b (hereafter referred to as the second fastened state). FIG. 13(b) shows a state where the screw 64b is fastened at the center of the first long hole 69a of the optical compensation sheet holder 6b (hereafter referred to as the third fastened state).

According to the first adjustment operation, as shown in FIGS. 13(a)-(c), the attachment posture of the optical compensation sheet holder 6b can be adjusted between the first fastened state and second fastened state.

FIGS. 14(a)-(c) show the optical compensation sheet holder 6b, the attachment posture of which is adjusted by the second adjustment operation.

As shown in FIG. 11, the slide member 63 of the optical compensation sheet holder 6b is fastened to the turning mem-

## 12

ber 62 by the screw 64a through the second long hole 69c of the slide member 63. Loosening the screw 64a allows slide operation of the slide member 63 along the optical axis within the second long hole 69c.

Because the projection 61b of the frame 61 is pinched by the pinching part 63b of the slide member 63, the projection 61b of the frame 61 moves along the optical axis together with the slide member 63. This causes the frame 61 to turn on the pair of shanks 61a, 61a formed along one diagonal of the optical compensation sheet 42b, so that a surface of the optical compensation sheet 42b fixed to the frame 61 is inclined relative to a plane perpendicular to the optical axis.

FIG. 14(a) shows a state where the screw 64a is fastened at the front end of the second long hole 69c of the slide member 63 (hereafter referred to as the fourth fastened state). In the fourth fastened state, the upper left end of the frame 61 having the projection 61b protruded therefrom projects forward along the optical axis more than the lower right end of the frame 61.

On the other hand, FIG. 14(c) shows a state where the screw 64a is fastened at the rear end of the second long hole 69c (hereafter referred to as the fifth fastened state). In the fifth fastened state, the upper left end of the frame 61 retreats along the optical axis backward more than the lower right end of the frame 61.

FIG. 14(b) shows a state where the screw 64a is fastened at the center of the second long hole 69c (hereafter referred to as the sixth fastened state). In the sixth fastened state, the optical compensation sheet 42b fixed to the frame 61 has a surface approximately perpendicular to the optical axis.

According to the second adjustment operation, as shown in FIGS. 14(a)-(c), the attachment posture of the optical compensation sheet holder 6b can be adjusted between the fourth fastened state and fifth fastened state.

The attachment posture of the optical compensation sheet holder 6b is adjusted before shipment of the liquid crystal projector device. Specifically, the attachment posture of the optical compensation sheet holder 6b is adjusted by projecting an adjustment image using the liquid crystal projector device and using the first and second adjustment operations to ensure that the adjustment image has a clear black-and-white contrast.

According to the first adjustment operation, the optical compensation sheet 42b can be adjusted in its attachment posture turnably within a plane perpendicular to the optical axis. Therefore, the slow axis of the liquid crystal molecules in the optical compensation sheet 42b viewed from the optical axis direction can be set approximately parallel to an alignment direction of liquid crystal molecules of the liquid crystal panel 43b shown in FIG. 5.

According to the second adjustment operation, the inclination angle of the surface of the optical compensation sheet 42b relative to a plane perpendicular to the optical axis is adjustable. Therefore, the apparent slow axis of the optical compensation sheet 42b can correspond to the slow axis in the optical axis direction of the liquid crystal molecules in the liquid crystal panel 43b shown in FIG. 5.

Further, the above second adjustment operation can incline the surface of the optical compensation sheet 42b relative to the optical axis on the rotation axis approximately parallel to one diagonal of the liquid crystal panel 43b. That is, because the surface of the optical compensation sheet 42b can be inclined relative to one diagonal of the liquid crystal panel 43b, the attachment posture of the optical compensation sheet holder 6b is adjusted more easily than conventionally.

Furthermore, as shown in FIG. 11, the optical compensation sheet 42b is fixed to the frame 61, and the frame 61 is



## 13

supported by the turning member **62** turnably on the rotation axis. Therefore, the frame **61** and optical compensation sheet **42b** will not experience any unnatural force in adjustment with the second adjustment operation. This can prevent warpages and flexures from occurring in the frame **61** and optical compensation sheet **42b**, and, as a result, provide a uniform projection image with a clearer contrast than a conventional one, and without uneven coloring or the like.

## Lens Shift Mechanism 2

As shown in FIG. 2, the projection lens system includes the projection lens **20** and cylinder **21** for holding the projection lens. The projection lens system is held by the lens shift mechanism **2**, and attached to the forward end of the optical system holding case **30**. The lens shift mechanism **2** is for horizontally and vertically reciprocatingly moving the projection lens system within a certain range where the brightness of color image light will not be significantly reduced.

The projector device with the lens shift mechanism **2** makes it easier than ever to adjust an image display position relative to a screen because the lens shift mechanism **2** makes it possible to adjust the image display position relative to the screen after appropriately positioning the projector device relative to the screen.

As shown in FIG. 15 and FIG. 16, the lens shift mechanism **2** includes a stationary base **120**, a movable member **125** to which the projection lens system is attached, a vertical drive mechanism **23** for vertically driving the movable member **125**, and a horizontal drive mechanism **22** for horizontally driving the movable member **125**.

As shown in FIG. 17 and FIG. 19, the stationary base **120** includes a metal front plate **122** screwed on the front of a metal back case **121**. The back case **121** and front plate **122** have circular openings **121a**, **122b**, respectively, formed centrally therein. The cylinder **21** is to be inserted into both openings **121a**, **122b**.

The movable member **125** includes a vertically movable plate **123** and a horizontally movable plate **124** in close contact with each other, and is placed inside the stationary base **120**. The vertically movable plate **123** and horizontally movable plate **124** are generally rectangular. Both movable plates **123**, **124** have circular openings **123c**, **124c**, respectively, formed centrally therein, into which the cylinder **21** is to be inserted.

As shown in FIG. 17, the cylinder **21** has an outer peripheral surface thereof formed with a rectangular flange **21a**. The cylinder **21** is to be attached to the movable member **125** with the flange **21a** held between the horizontally movable plate **124** and vertically movable plate **123**.

As shown in FIG. 19, the vertically movable plate **123** has four vertical guide pins **123a**, **123a**, **123b**, **123b** protruded from a front surface thereof toward the horizontally movable plate **124**. The horizontally movable plate **124** is provided with two vertically long slot-like guide holes **124b**, **124b**. The two lower vertical guide pins **123a**, **123a** of the vertically movable plate **123** are to penetrate through the respective guide holes **124b**, **124b**. The horizontally movable plate **124** has a back surface thereof provided with two vertically long slot-like guide grooves **124d**, **124d**. The two upper vertical guide pins **123b**, **123b** of the vertically movable plate **123** are to engage with the respective guide grooves **124d**, **124d**.

The horizontally movable plate **124** has a right end thereof formed with a horizontally extending rack **126**. The rack **126** is to engage with a last stage pinion **27b** constituting the horizontal drive mechanism **22** shown in FIG. 18. As shown in FIG. 19, the horizontally movable plate **124** has two horizontal guide pins **124a**, **124a** protruded from upper opposite

## 14

ends of a front surface thereof toward the front plate **122**, while the front plate **122** has two horizontally long slot-like guide holes **122a**, **122a** provided therein. The two horizontal guide pins **124a**, **124a** of the horizontally movable plate **124** are to penetrate through both guide holes **122a**, **122a**, respectively.

As shown in FIG. 17 and FIG. 18, the horizontal drive mechanism **22** includes a horizontal operation dial **24** to be operated by a user, and a plurality of transmission gears **24a**, **25**, **26**, **27** for converting rotary motion of the horizontal operation dial **24** to linear motion of the horizontally movable plate **124**. As shown in FIG. 1, the horizontal operation dial **24** is partly exposed from the right side wall of the casing **1**.

As shown in FIG. 18, the horizontal operation dial **24** is disposed rotatably on a vertical rotation axis. The spur gear **24a** is provided on the reverse surface of the horizontal operation dial **24**. The spur gear **24a** is engaged with a spur gear **25a** of the first transmission gear **25**, which rotates on a vertical rotation axis. The spur gear **25a** is engaged with a spur gear **26a** of the second transmission gear **26**, which rotates on a vertical rotation axis. The second transmission gear **26** has a worm **26b** engaged with a worm wheel **27a** formed at one end of the third transmission gear **27**, which rotates on a rotation axis along the optical axis of the projection lens system. The rack **126** of the horizontally movable plate **124** is engaged with the pinion **27b** of the third transmission gear **27**.

The vertical drive mechanism **23** includes a vertical operation dial **28** to be operated by a user, a plurality of transmission gears **28a**, **29**, **130**, **131** for converting rotary motion of the vertical operation dial **28** to linear motion of the vertically movable plate **124**, a turning plate **127** and a connection plate **128**. As shown in FIG. 1, the vertical operation dial **28** is partly exposed from the right side wall of the casing **1**.

The vertical operation dial **28** is disposed rotatably on a rotation axis along the optical axis. The spur gear **28a** is provided on the reverse surface of the vertical operation dial **28**. The spur gear **28a** is engaged with a spur gear **29a** at one end of the fourth transmission gear **29**, which rotates on a rotation axis along the optical axis. The fourth transmission gear **29** has a face gear **29b** at the other end thereof engaged with a bevel gear **130a** formed at one end of the fifth transmission gear **130**. The fifth transmission gear **130** has a worm **130b** engaged with a worm wheel **131a** at one end of the sixth transmission gear **131**, which rotates on a rotation axis along the optical axis. The sixth transmission gear **131** has a spur gear **131b** at the other end thereof engaged with a sector gear portion **127a** of the turning plate **127** shown in FIG. 17 and FIG. 19.

As shown in FIG. 19, the turning plate **127** has an axial bore **127b** provided centrally therein. The turning plate **127** is attached to the front plate **122** of the stationary base **120** by a support pin **132** through the axial bore **127b** turnably on the support pin **132**. The sector gear portion **127a** is formed at the right end of the turning plate **127**, while the turning plate **127** has a left end thereof provided with a through hole **127c**. The turning plate **127** is connected to the connection plate **128** by a connection pin **129** through the through hole **127c**.

The connection plate **128** has both right and left ends thereof provided with screw holes **128a**, **128a**, respectively. The connection plate **128** is fixed to the lower end of the vertically movable plate **123** with two screws through both screw holes **128a**, **128a** fastened to top ends of the two lower vertical guide pins **123a**, **123a** of the vertically movable plate **123** exposed from the opening **122b** of the front plate **122**.

The connection plate **128** has a horizontally long slot-like engagement hole **128b** provided centrally therein. The connection pin **129** is through the engagement hole **128b**. There-



## 15

fore, the connection plate **128** and turning plate **127** are to be connected to each other such that the connection plate **128** can be horizontally displaced relative to the turning plate **127** within the engagement hole **128b**.

When a user rotates the horizontal operation dial **24** clockwise, the horizontal operation dial **24** transmits its turning force via the plurality of transmission gears **24a**, **25**, **26**, **27** constituting the above horizontal drive mechanism **22** to the rack **126** of the horizontally movable plate **124** shown in FIG. **15**. The horizontal guide pins **124a** of the horizontally movable plate **124** are then guided by the respective horizontal guide holes **122a** of the front plate **122a** to slide the horizontally movable plate **124** leftward.

The vertically movable plate **123** can be horizontally displaced relative to the turning plate **127** within the engagement hole **128b** of the connection plate **128**. Further, the vertically movable plate **123** is restrained from being horizontally displaced relative to the horizontally movable plate **124** by engagement of the two lower vertical guide pins **123a**, **123a** of the vertically movable plate **123** with the vertical guide holes **124b**, **124b** of the horizontally movable plate **124**, and engagement of the two upper vertical guide pins **123b**, **123b** shown in FIG. **19** with the vertical guide grooves **124d**, **124d** of the horizontally movable plates **124**. Therefore, the vertically movable plate **123** and the projection lens system attached to the vertically movable plate **123** slide horizontally together with the horizontally movable plate **124** as shown in FIG. **15**.

Similarly, when a user rotates the horizontal operation dial **24** counterclockwise, the horizontally movable plate **124**, vertically movable plate **123** and projection lens system slide rightward.

In FIG. **15**, the dashed line shows the horizontally movable plate **124** and vertically movable plate **123** slid leftward to the limit position, and the double-dashed line shows the horizontally movable plate **124** and vertically movable plate **123** slid rightward to the limit position. The solid line shows the horizontally movable plate **124** and vertically movable plate **123** in the horizontally central position. The central position can provide the brightest projection image. As the horizontally movable plate **124** and vertically movable plate **123** move leftward or rightward away from the central position, the brightness of the projection image slightly lowers.

As shown in FIG. **15**, when the horizontally movable plate **124** and vertically movable plate **123** are in the horizontally central position, the connection pin **129** is positioned on a vertically extending line through the centroid of the projection lens system.

When a user rotates the vertical operation dial **28** clockwise, the vertical operation dial **28** transmits its turning force via the plurality of transmission gears **28a**, **29**, **130**, **131** constituting the vertical drive mechanism **23** shown in FIG. **18** to the sector gear portion **127a** of the turning plate **127** shown in FIG. **16**. The turning plate **127** then turns counterclockwise on the support pin **132**, causing the left end of the turning plate **127** to move downward.

The turning plate **127** has the connection plate **128** connected to the left end thereof via the connection pin **129**. The connection plate **128** is fixed to the vertically movable plate **123**. Therefore, as the turning plate **127** turns counterclockwise, the two lower vertical guide pins **123a**, **123a** of the vertically movable plate **123** are guided by the vertical guide holes **124b**, **124b** of the horizontally movable plate **124**, and the two upper vertical guide pins **123b**, **123b** shown in FIG. **19** are guided by the vertical guide grooves **124d**, **124d** of the horizontally movable plate **124**, to move the vertically mov-

## 16

able plate **123** and the projection lens system attached to the vertically movable plate **123** downward relative to the horizontally movable plate **124**.

On the other hand, when a user rotates the vertical operation dial **28** counterclockwise, the turning plate **127** turns clockwise on the support pin **132**, causing the left end of the turning plate **127** to move upward. This causes the vertically movable plate **123** and the projection lens system to be displaced upward relative to the horizontally movable plate **124**.

In FIG. **16**, the dashed line shows the vertically movable plate **123** slid upward to the limit position, and the double-dashed line shows the vertically movable plate **123** slid downward to the limit position. The solid line shows the vertically movable plate **123** in the vertically central position. The central position can provide the brightest projection image. As the vertically movable plate **123** moves upward or downward away from the central position, the brightness of the projection image slightly lowers.

The above lens shift mechanism **2** makes it possible to minimize the turning force to act on the vertically movable plate **123** due to the self-weight of the projection lens system in vertical shift operation of the projection lens system because the turning plate **127** constituting the vertical drive mechanism **23** and the vertically movable plate **123** having the projection lens system attached thereto are connected to each other by the connection pin **129** on a vertically extending line through the centroid of the projection lens system. This enables the projection lens system to be vertically driven smoothly.

As shown in FIG. **20** and FIG. **21**, the lens shift mechanism **2** includes a lock mechanism **140** for fixing the projection lens system in a desired position. The lock mechanism **140** is for fixing the projection lens system in place after adjusting an image projected from the liquid crystal projector device in place in accordance with a forward screen using the lens shift mechanism **2** in setting of the liquid crystal projector device. The lock mechanism **140** eliminates the necessity of later readjustment unless the liquid crystal projector device or screen is moved.

As shown in FIG. **21**, the lock mechanism **140** includes the lever member **133** slidable along the optical axis of the projection lens system, a horizontal lock member **137** to disengageably engage with the spur gear **24a** of the horizontal operation dial **24**, and a vertical lock member **136** to disengageably engage with the spur gear **28a** of the vertical operation dial **28**, in accordance with slide operation of the lever member **133**. As shown in FIG. **20**, the lever member **133** is attached to an attachment plate **139** fastened to the stationary base **120**, and slidable along the optical axis between an unlocked position indicated by the solid line and a locked position indicated by the double-dashed line in the drawing. As shown in FIG. **1**, the knob **134** of the lever member **133** is exposed from the right side wall of the casing **1**.

In adjustment of the image projection position using the lens shift mechanism **2**, the lever member **133** is set in the unlocked position. After completion of the adjustment, the knob **134** of the lever member **133** is operated to slide the lever member **133** to the locked position, whereby the horizontal lock member **137** and vertical lock member **136** shown in FIG. **21** are engaged with the spur gears **24a**, **28a** of the horizontal operation dial **24** and vertical operation dial **28** constituting the lens shift mechanism **2**, to disable both operation dials **24**, **28** from rotating. This enables the projection lens system to be fixed in a desired position.

If the image projection position needs readjustment, the knob **134** of the lever member **133** is operated to slide the lever member **133** to the unlocked position, whereby the



17

horizontal lock member **137** and vertical lock member **136** shown in FIG. **21** are disengaged from the spur gears **24a**, **28a** of the horizontal operation dial **24** and vertical operation dial **28** constituting the lens shift mechanism **2**, to enable both operation dials **24**, **28** to rotate.

FIG. **22(a)** and FIG. **22(b)** show a relative position relationship between the lever member **133** and vertical lock member **136**, with the lever member **133** set in the locked position or unlocked position. As shown in FIG. **22(a)** and FIG. **22(b)**, the vertical lock member **136** is approximately L-shaped, and attached to the attachment plate **139** shown in FIG. **20** turnably on a rotation axis **136b** along the optical axis. The vertical lock member **136** has one end thereof formed with a gear portion **136a**.

The rotation axis **136b** of the vertical lock member **136** has a torsion spring **141** fitted therearound. The torsion spring **141** has one end thereof locked on the attachment plate **139**, and the other end hung on the back surface of the gear portion **136a** of the vertical lock member **136**.

The elastic restoring force of the torsion spring **141** causes counterclockwise turning force to act on the vertical lock member **136**. The gear portion **136a** of the vertical lock member **136** is always biased by the turning force toward the spur gear **28a** of the vertical operation dial **28**.

When the lever member **133** is set in the locked position, the lever member **133** is positioned rearward along the optical axis, as indicated by the double-dashed line in FIG. **20**. In this state, the lever member **133** has an end **133a** thereof spaced apart from the vertical lock member **136** as shown in FIG. **22(a)**. The gear portion **136a** of the vertical lock member **136** is engaged with the spur gear **28a** of the vertical operation dial **28** by the biasing force of the torsion spring **141**. This results in the vertical operation dial **28** disabled from rotating.

On the other hand, when the lever member **133** is set in the unlocked position, the lever member **133** is positioned forward along the optical axis, as indicated by the solid line in FIG. **20**. In this state, the end **133a** of the lever member **133** touches one end of the vertical lock member **136** as shown in FIG. **22(b)**. This causes the vertical lock member **136** to turn counterclockwise against the biasing force of the torsion spring **141**.

Consequently, the gear portion **136a** formed at the other end of the vertical lock member **136** moves away from the spur gear **28a** of the vertical operation dial **28**. This results in the vertical operation dial **28** enabled to rotate.

FIG. **23(a)** and FIG. **23(b)** show a relative position relationship between the lever member **133** and horizontal lock member **137**, with the lever member **133** set in the locked position or unlocked position. As shown in FIG. **23(a)** and FIG. **23(b)**, the horizontal lock member **137** is approximately L-shaped, and attached to the attachment plate **139** shown in FIG. **20** turnably on a vertical rotation axis **137b**. The horizontal lock member **137** has one end thereof formed with a gear portion **137a**.

The rotation axis **137b** of the horizontal lock member **137** has a torsion spring **141** fitted therearound. The torsion spring **141** has one end thereof locked on the attachment plate **139**, and the other end hung on the back surface of the gear portion **137a** of the horizontal lock member **137**.

The elastic restoring force of the torsion spring **141** causes counterclockwise turning force to act on the horizontal lock member **137**. The gear portion **137a** of the horizontal lock member **137** is always biased by the turning force toward the spur gear **24a** of the horizontal operation dial **24**.

When the lever member **133** is set in the locked position, the lever member **133** is positioned rearward along the optical axis, as indicated by the double-dashed line in FIG. **20**. In this

18

state, the lever member **133** has an end **133b** thereof spaced apart from the horizontal lock member **137** as shown in FIG. **23(a)**. The gear portion **137a** of the horizontal lock member **137** is engaged with the spur gear **24a** of the horizontal operation dial **24** by the biasing force of the torsion spring **141**. This results in the horizontal operation dial **24** disabled from rotating.

On the other hand, when the lever member **133** is set in the unlocked position, the lever member **133** is positioned forward along the optical axis, as indicated by the solid line in FIG. **20**. In this state, the end **133b** of the lever member **133** touches one end of the horizontal lock member **137** as shown in FIG. **23(b)**. This causes the horizontal lock member **137** to turn clockwise against the biasing force of the torsion spring **141**.

Consequently, the gear portion **137a** formed at the other end of the horizontal lock member **137** moves away from the spur gear **24a** of the horizontal operation dial **24**. This results in the horizontal operation dial **24** enabled to rotate.

Therefore, the liquid crystal projector device of the present invention can realize, with a simple structure, the lock mechanism **140** capable of simultaneously setting the two operation dials **24**, **28** so as to rotate or not to rotate, with slide operation of the single lever member **133**.

The lens shift mechanism **2** further includes a first click-feeling generation mechanism **150** for giving a certain click-feeling to the horizontal operation dial **24** when operation of the horizontal operation dial **24** brings the projection lens system into the horizontally central position indicated by the solid line in FIG. **15**, and a second click-feeling generation mechanism **151** for giving a certain click-feeling to the operation of the vertical operation dial **28** when operation of the vertical operation dial **28** brings the projection lens system into the vertically central position indicated by the solid line in FIG. **16**.

As shown in FIG. **24(a)** and FIG. **24(b)**, the first click-feeling generation mechanism **150** includes a first whorl groove **150a** provided in a side surface of the first transmission gear **25** constituting the horizontal drive mechanism **22**, a first turning member **135** to slide on the first whorl groove **150a** along with rotation of the first transmission gear **25**, and a torsion spring **153** fitted around a rotation axis **135a** of the first turning member **135**. The first turning member **135** is attached to the attachment plate **139** shown in FIG. **20** turnably on the vertical rotation axis **135a** provided at one end of the first turning member **135**.

The first turning member **135** has the other end thereof formed with a projection **135b** projecting toward the first transmission gear **25**. The projection **135b** is engaged with the first whorl groove **150a**. The first turning member **135** has a clockwise turning force on the rotation axis **135a** caused by the elastic restoring force of the torsion spring **153**, whereby the projection **135b** is biased toward the inner peripheral wall surface of the first whorl groove **150a**.

Therefore, when a user rotates the horizontal operation dial **24** to thereby rotate the first transmission gear **25**, the projection **135b** of the first turning member **135** slides on the first whorl groove **150a** while contacting the inner peripheral wall surface of the first whorl groove **150a**.

When the rotation of the horizontal operation dial **24** brings the projection lens system into the horizontally central position indicated by the solid line in FIG. **15**, the projection **135b** of the first turning member **135** is engaged by the biasing force of the torsion spring **153** with a recess **150b** provided on the inner peripheral wall surface of the first whorl groove **150a**, as shown in FIG. **24(b)**.



The certain click-feeling will be given to the operation of the horizontal operation dial **24** by a collision made when the projection **135b** of the first turning member **135** engages with the recess **150b** of the first whorl groove **150a**. In order to further rotate the horizontal operation dial **24** from this state, it is necessary to disengage the projection **135b** of the first turning member **135** from the recess **150b** of the first whorl groove **150a** against the biasing force of the torsion spring **153**. This will give a certain resistance force to the rotation operation of the horizontal operation dial **24**.

As shown in FIG. **25(a)** and FIG. **25(b)**, the second click-feeling generation mechanism **151** includes a second whorl groove **151a** provided in a side surface of the fourth transmission gear **29** constituting the vertical drive mechanism **23**, a second turning member **138** to slide on the second whorl groove **151a** along with rotation of the fourth transmission gear **29**, and a coil spring **155** for giving a clockwise turning force to the second turning member **138**.

The second turning member **138** is approximately L-shaped, and attached to the attachment plate **139** shown in FIG. **15** and FIG. **16** turnably on the rotation axis **138a** extending along the optical axis direction. The coil spring **155** is stretched between one end of the second turning member **138** and the attachment plate **139**.

As shown in FIG. **25(a)** and FIG. **25(b)**, the second turning member **138** has the other end thereof formed with a projection **138b** projecting toward the fourth transmission gear **29**. The projection **138b** is engaged with the second whorl groove **151a**. The second turning member **138** has a clockwise turning force on the rotation axis **138a** caused by the elastic restoring force of the coil spring **155**, whereby the projection **138b** is biased toward the inner peripheral wall surface of the second whorl groove **151a**.

Therefore, when a user rotates the vertical operation dial **28** to thereby rotate the fourth transmission gear **29**, the projection **138b** of the second turning member **138** slides on the second whorl groove **151a** while contacting the inner peripheral wall surface of the second whorl groove **151a**.

When the rotation of the vertical operation dial **28** brings the projection lens system into the vertically central position indicated by the solid line in FIG. **16**, the projection **138b** of the second turning member **138** is engaged by the biasing force of the coil spring **155** with a recess **151b** provided on the inner peripheral wall surface of the second whorl groove **151a**, as shown in FIG. **25(b)**.

The certain click-feeling will be given to the operation of the vertical operation dial **28** by a collision made when the projection **138b** of the second turning member **138** engages with the recess **151b** of the second whorl groove **151a**. In order to further rotate the vertical operation dial **28** from this state, it is necessary to disengage the projection **138b** of the second turning member **138** from the recess **151b** of the second whorl groove **151a** against the biasing force of the coil spring **155**. This will give a certain resistance force to the rotation operation of the vertical operation dial **28**.

According to the above liquid crystal projector device of the present invention, when adjusting the image projection position with the lens shift mechanism **2**, a user can recognize, due to the click-feelings of both operation dials **24**, **28**, the horizontally and vertically central positions, which give a projection image with the maximum brightness. This allows adjustment of the image projection position with reference to the horizontally and vertically central positions. Consequently, the image projection position is adjusted more easily than conventionally.

#### Lamp Unit 7

As shown in FIG. **2**, the lamp unit **7** providing a light source is attached to the left end of the optical system holding case **30**. As shown in FIG. **26**, the lamp unit **7** includes a reflector **71** having an ellipsoidal reflecting surface and joined to a rectangular frame **72**. As shown in FIG. **34**, the reflector **71** has a lamp bulb **170** providing the light source arranged at the focal position thereof. The lamp bulb **170** includes a luminous body enclosed inside a columnar glass tube **171**. A light emitting portion **172** enclosing the luminous body is spherical.

As shown in FIG. **26** and FIG. **27**, the frame **72** has a rectangular opening **72a**. A concave lens **80** is fitted in the opening **72a**. As shown in FIG. **35(a)**, the concave lens **80** has a concave surface **80a** on the light emergence surface. As shown in FIG. **35(b)**, the concave lens **80** has a concavity **80b** formed only centrally on the light incidence surface.

As shown in FIG. **3**, the lamp cooling fan **190** for cooling the lamp unit **7** is arranged at the rear left end of the casing **1**. As shown in FIG. **26** and FIG. **27**, the lamp unit **7** has the lamp cooling fan **190** facing side formed with three air introduction openings **74a**, **73**, **74b** for introducing the air drawn from the lamp cooling fan **190** toward the lamp bulb **170** shown in FIG. **34**. Formed on the opposite side of the lamp unit **7** is an air discharge opening **75** for discharging the air introduced from the three air introduction openings **74a**, **73**, **74b**.

The lamp unit **7** is a user replacement part because its performance deteriorates due to long use. This requires that the lamp unit **7** have an attachment structure that allows easy attachment/detachment. If the lamp unit **7** is attached slantingly relative to the optical system holding case **30**, then the brightness of the projection image lowers. Therefore, it is required that the lamp unit **7** have an attachment structure that allows the lamp unit **7** to be easily attached/detached, as well as ensuring that the lamp unit **7** can be positioned in a particular place relative to the optical system holding case **30**.

As shown in FIG. **29**, in the projector device of the present invention, the lamp unit **7** can be attached to and detached from the left end of the optical system holding case **30** by sliding along a plane perpendicular to the optical axis of the optical system **3** disposed in the optical system holding case **30**.

The optical system holding case **30** has an upper wall and a lower wall of the left end thereof provided with two positioning holes **330a**, **330b** and two positioning pins **331**, **331** for positioning the lamp unit **7**. The two positioning holes **330a**, **330b** and two positioning pins **331**, **331** are adjacently provided at a certain distance in the direction perpendicular to the optical axis of light emitted from the lamp unit **7**.

As shown in FIG. **28** and FIG. **29**, the frame **72** of the lamp unit **7** has, protruded upward from an upper surface thereof, two fitting pins **76**, **76** to fit into the two positioning holes **330a**, **330b** of the optical system holding case **30**, while, as shown in FIG. **26** and FIG. **27**, the frame **72** has a lower end thereof provided with two fitting holes **77**, **77**. The two positioning pins **331**, **331** of the optical system holding case **30** shown in FIG. **29** are to be fitted into both fitting holes **77**, **77**.

The fitting pins **76** have an outer diameter of 5 mm, and the positioning holes **330a**, **330b** have an inner diameter of 5.1 mm. The positioning pins **331** have an outer diameter of 4 mm, and the fitting holes **77** have an inner diameter of 4.1 mm.

As shown in FIG. **29** and FIG. **30**, the optical system holding case **30** has a sheet metal, rectangular frame-like flat spring member **340** attached to the left end thereof. As shown in FIG. **30**, the flat spring member **340** is attached to the left end of the optical system holding case **30** with hook holes



341, 341 provided on opposite upper ends engaged with hooks 333, 333 protruded from inner surfaces of opposite side walls of the optical system holding case 30, and with L-shaped bent portions 346, 346 provided on opposite lower ends inserted in a slit groove 335 provided in the lower end of the optical system holding case 30.

The flat spring member 340 has a first flat portion 345 to contact an end surface 334 of the left end of the optical system holding case 30, a second flat portion 344 projecting from the first flat portion 345 toward the lamp unit 7, and inclined portions 342, 343 connecting the first flat portion 345 and second flat portion 344.

When the lamp unit 7 is attached to the optical system holding case 30, as shown in FIG. 29, the two fitting pins 76, 76 formed on the frame 72 of the lamp unit 7 are inserted into the two positioning holes 330a, 330b of the optical system holding case 30 from beneath the optical system holding case 30.

As shown in FIG. 26, FIG. 27 and FIG. 29, taper machining is applied to tips 76a, 76a of the two fitting pins 76, 76 of the frame 72 to thereby give the two fitting pins 76, 76 a tapered shape. Further, as shown in FIG. 32(a) and FIG. 32(b), one positioning hole 330a of the two positioning holes 330a, 330b of the optical system holding case 30 has a shape longer in the direction perpendicular to the optical axis direction. Therefore, the two fitting pins 76, 76 of the frame 72 can be easily inserted into the two positioning holes 330a, 330b of the optical system holding case 30.

FIG. 32(a) shows the tips 76a, 76a of the two fitting pins 76, 76 of the frame 72 inserted in the two positioning holes 330a, 330b of the optical system holding case 30. FIG. 33(a) shows the deformation of the flat spring member 340 in this state. In this state, an end surface 72b of the frame 72 is only in contact with the second flat portion 344 of the flat spring member 340, and does not deform the flat spring member 340.

When the lamp unit 7 is further inserted from this state, an end of the lamp unit 7 contacts the lower surface of the upper wall of the optical system holding case 30, which receives the lamp unit 7, while the two positioning pins 331, 331 of the optical system holding case 30 shown in FIG. 29 and FIG. 30 are fitted into the two fitting holes 77, 77 formed in the lower end of the frame 72 of the lamp unit 7 shown in FIG. 29. As shown in FIG. 28, the lamp unit 7 is thus attached to the left end of the optical system holding case 30.

FIG. 31 and FIG. 32(b) show the lamp unit 7 attached to the left end of the optical system holding case 30. FIG. 33(b) shows the deformation of the flat spring member 340 in this state. In this state, as shown in FIG. 31 and FIG. 33(b), the end surface 72b of the frame 72 pushes the second flat portion 344 of the flat spring member 340, whereby the flat spring member 340 is pressed between the end surface 72b of the frame 72 and the end surface 334 of the optical system holding case 30. This causes the elastic deformation in the flat spring member 340.

The lamp unit 7 is pushed away from the optical system holding case 30 by the elastic restoring force of this flat spring member 340. Because the fitting pin 76 is columnar and the first positioning hole 330b is circular, the centering effect due to the engagement of both causes the fitting pin 76 to move to a position where its central axis and the center of the first positioning hole 330b stand in a line parallel to the optical axis.

Consequently, as shown in FIG. 32(b), the lamp unit 7 is positioned, in the direction along the optical axis, in a place where outer peripheral surfaces of the fitting pins 76, 76 of the frame 72 are in contact with lamp unit 7 side end edges of the respective positioning holes 330a, 330b of the optical system

holding case 30, and, in the direction perpendicular to the optical axis, in a place where the central axis of the lower fitting pin 76 and the center of the lower positioning hole 330b stand in a line parallel to the optical axis.

According to the above attachment structure of the lamp unit 7, a user can easily replace the lamp unit 7, and can incorporate the lamp unit 7 into the device with high accuracy.

It is known that in light emission of the lamp bulb 170 shown in FIG. 34, the temperature at the vertically upper side of the lamp bulb 170 is higher than the temperature at the lower side thereof, which results in the temperature difference between above and below the lamp bulb 170. This temperature difference between above and below is the greatest at the light emitting portion 172 of the lamp bulb 170. In order to fully bring out the performance of the lamp bulb 170, it is necessary to maintain the temperature of the lamp bulb 170 below a certain temperature, as well as to cool the lamp bulb 170 such that the temperature difference between above and below is held within a certain range.

FIG. 39(a) shows air flows in the lamp unit 7 in the case where the liquid crystal projector device is set as shown in FIG. 1. As shown in FIG. 39(a), among the three air introduction openings 74a, 73, 74b for introducing the air drawn from the lamp cooling fan 190 toward the lamp bulb 170, the first air introduction opening 74a and second air introduction opening 74b are formed at opposite sides of a plane passing through a central axis of the lamp bulb 170 and perpendicular to a side wall of the lamp unit 7, and open toward the light emitting portion 172 of the lamp bulb 170. The third air introduction opening 73 is formed between the first air introduction opening 74a and second air introduction opening 74b, and open toward an end of the glass tube 171 of the lamp bulb 170.

Therefore, the air drawn from the lamp cooling fan 190 shown in FIG. 3 is forcibly separated by part of the side wall of the lamp unit 7 intervening between the first air introduction opening 74a and second air introduction opening 74b, so that the air introduced from the first air introduction opening 74a will flow above the light emitting portion 172 of the lamp bulb 170, and the air introduced from the second air introduction opening 74b will flow below the light emitting portion 172 of the lamp bulb 170. The air introduced from the third air introduction opening 73 will flow toward the end of the lamp bulb 170.

The liquid crystal projector device of the present invention can be attached with an attachment hardware to a ceiling or a vertical wall opposed to a screen with the bottom surface shown in FIG. 1 providing an attachment surface. The liquid crystal projector device of the present invention has functions for rotating by 180 degrees and vertically flipping an image to be projected so as to allow the image to be projected on a screen in a normal direction regardless of its setting. When the liquid crystal projector device is set by being hung from a ceiling, its setting is vertically reversed from the setting shown in FIG. 1, and therefore projection images are rotated by 180 degrees.

When attached to a vertical wall opposed to a screen, the liquid crystal projector device is set with the projection lens 20 shown in FIG. 1 facing vertically upward or downward. Images can be projected forward by a mirror arranged at an inclination angle of 45 degrees relative to an optical axis of image light projected from the projection lens 20. When it is set with the projection lens 20 facing vertically downward, projection images are vertically flipped.

FIG. 39(b) shows air flows in the lamp unit 7 in the case where the liquid crystal projector device is hung from a ceiling. In this setting state, the air drawn from the lamp cooling



fan 190 shown in FIG. 3 is forcibly separated by part of the side wall of the lamp unit 7 intervening between the first air introduction opening 74a and second air introduction opening 74b, so that the air introduced from the first air introduction opening 74a will flow below the light emitting portion 172 of the lamp bulb 170, and the air introduced from the second air introduction opening 74b will flow above the light emitting portion 172 of the lamp bulb 170. The air introduced from the third air introduction opening 73 will flow toward the end of the lamp bulb 170.

FIG. 39(c) and FIG. 39(d) show air flows in the lamp unit 7 in the case where the liquid crystal projector device is attached to the vertical wall. In this setting state, the air drawn from the lamp cooling fan 190 shown in FIG. 3 is forcibly separated by part of the side wall of the lamp unit 7 intervening between the first air introduction opening 74a and second air introduction opening 74b, so that the air introduced from the first air introduction opening 74a and second air introduction opening 74b will flow through both right and left sides of the light emitting portion 172 of the lamp bulb 170. The air introduced from the third air introduction opening 73 will flow toward the end of the lamp bulb 170.

Therefore, the air drawn from the lamp cooling fan 190 shown in FIG. 3 will not be vertically blown to the vertically lower surface of the light emitting portion 172 of the lamp bulb 170 in any of the above four settings. This prevents the low-temperature, vertically lower side of the light emitting portion 172 of the lamp bulb 170 from being excessively cooled. Consequently, the temperature difference between the vertically upper side and vertically lower side of the light emitting portion 172 of the lamp bulb 170 can be held within a certain range regardless of the setting of the device.

As shown in FIG. 36 through FIG. 38, the lamp unit 7 has attached thereto a cover member 184 for covering the lamp unit 7 in order to prevent leak light. As shown in FIG. 37, the cover member 184 has one side wall thereof provided with a first opening 186 at the opposed position to the three air introduction openings 74a, 73, 74b of the lamp unit 7. As shown in FIG. 38, the opposite side wall of the cover member 184 is provided with a second opening 187 at the opposed position to the air discharge opening 75 of the lamp unit 7, and has attached thereto a channel housing 180 for constituting a channel for the air discharged from the second opening 187.

As shown in FIG. 36 and FIG. 38, the channel housing 180 has a slit-like through hole 181 formed in a side wall thereof intersectingly with the flow of air flowing in the channel housing 180, while, as shown in FIG. 37 and FIG. 38, the channel housing 180 has an air filter 182 of porous material attached to the termination end thereof. The lamp bulb 170 shown in FIG. 37 can explode due to long use. When the lamp bulb 170 explodes, the gas enclosed in the lamp bulb 170 will be discharged. The air filter 182 has a function for adsorbing particulates included in the gas to thereby prevent the particulates included in the gas from being discharged outside the device. A HEPA (High Efficiency Particulate Air) filter is used for the air filter 182.

FIG. 40(a) shows flows of air cooling the lamp bulb 170 in ordinary use. As shown in FIG. 40(a), the air drawn from the lamp cooling fan 190 is introduced inside the lamp unit 7 through the three air introduction openings 74a, 73, 74b of the lamp unit 7. The air having cooled the lamp bulb 170 and become high in temperature will flow through the air discharge opening 75 at the opposite side and the channel in the channel housing 180.

The high-temperature air will flow toward the termination end of the channel housing 180, but its flow velocity is not so high that the air cannot pass through the air filter 182. The

high-temperature air blocked by the air filter 182 will be discharged outside the channel housing 180 by suction of the exhaust fan 191 through the through hole 181.

In contrast, FIG. 40(b) shows flows of gas enclosed in the lamp bulb 170 in explosion of the lamp bulb 170. Because the gas is enclosed in the lamp bulb 170 under high pressure, the internal pressure of the reflector 71 of the lamp unit 7 and the channel housing 180 will drastically rise at the moment of explosion of the lamp bulb 170. This causes the gas to burst into the channel in the channel housing 180.

The gas has a high flow velocity, and therefore will flow along the channel in the channel housing 180, so that only a slight amount of the gas will be discharged outside the channel housing 180 from the through hole 181 formed intersectingly with the channel in the channel housing 180. Consequently, the gas will mostly flow toward the termination end of the channel in the channel housing 180, i.e. air filter 182.

The gas has also a high pressure, and therefore will not be blocked by the air filter 182. The particulates included in the gas will be adsorbed by the air filter 182 while the gas is passing through the air filter 182. Consequently, the purified gas will be discharged outside the channel housing 180 from the termination end of the channel housing 180.

Therefore, the lamp unit 7 of the present invention makes it possible to prevent the particulates included in the gas enclosed in the lamp bulb 170 from being discharged outside the device when the lamp bulb 170 explodes without losing cooling efficiency for the lamp bulb 170.

As mentioned above, the liquid crystal projector device of the present invention employs the ellipsoidal reflector 71 as a reflector constituting the lamp unit 7 shown in FIG. 34. Conventional liquid crystal projector devices have been using a lamp unit having a parabolic reflector. The lamp unit 7 having the ellipsoidal reflector 71 can give a smaller width of light emitted from the lamp unit 7 than that of a lamp unit having a parabolic reflector, whereby the device can be miniaturized.

As shown in FIG. 5, the liquid crystal projector device of the present invention employs the integrator lens illumination system using the two integrator lenses 31, 32. Therefore, as shown in FIG. 34, the concave lens 80 having the concave surface 80a on the light emergence side is attached to the front of the lamp unit 7 in order to collimate the light emitted from the lamp unit 7. As shown in FIG. 35(b), the concavity 80b is formed only centrally on the light incidence surface of the concave lens 80. The concave lens 80 has an effective diameter of 37 mm and a focal distance of 99 mm. The concavity 80b has an effective diameter of 10 mm and a focal distance of 48 mm.

As shown in FIG. 41, the light emitted from the concave lens 80 of the lamp unit 7 passes through cells 31a constituting the first integrator lens 31, is imaged on respective cells 32a of the second integrator lens 32 corresponding to the cells 31a, and reach through the slit plate 33 to the polarization beam splitter 34.

FIG. 43(a) shows arc images of the lamp unit 7 imaged on the polarization beam splitter 34, which are obtained by a computer simulation. FIG. 43(b) shows arc images of the lamp unit 7 imaged on the polarization beam splitter 34 in the case of using a conventional concave lens without the concavity 80b formed on the light incidence surface instead of the concave lens 80 of the present invention.

When the lamp unit 7 having the ellipsoidal reflector 71 is used as an illumination system, the light emitted from the light emitting portion 172 of the lamp unit 7 is reflected by the reflector 71, and condensed centrally of the concave lens 80.



Therefore, the light emitted from the concave lens **80** at its central portion has a high brightness compared with the light emitted from the periphery.

FIG. **42(a)** shows arc images **350** imaged on a plurality of central constituent cells **32a** of the second integrator lens **32** of the present invention. FIG. **42(b)** shows arc images **350** imaged on the plurality of central constituent cells **32a** of the second integrator lens **32** in the case of using the conventional concave lens without the concavity **80b** formed on the light incidence surface instead of the concave lens **80** of the present invention.

As shown in FIGS. **43(a)(b)**, arc images imaged centrally on the polarization beam splitter **34** are larger than arc images imaged on a plurality of peripheral constituent cells **32a**. As shown in FIGS. **42(a)(b)**, the arc images **350** are imaged on and beyond the respective central constituent cells **32a** of the second integrator lens **32**.

Each of the arc images **350** is caused to have distortion by the aberration caused by the reflector **71**, concave lens **80** and first integrator lens **31** of the lamp unit **7**. Therefore, each of the arc images **350** is in the form of an approximate ellipse along a diagonal of the respective cells **32a**. In FIGS. **42(a)(b)**, hatching shows areas where light is blocked by the slit plate **33**. Light is blocked by the slit plate **33** in areas of each of the arc images **350** not exposed from the slit apertures **33a** of the slit plate **33**.

Therefore, it is important to reduce the amount of light blocked by the-slit plate **33** in order to improve utilization efficiency of the light emitted from the lamp unit **7**. For this purpose, it is necessary to increase the area of arc images **350** imaged on respective cells of the second integrator lens **32** corresponding to open areas of the slit apertures **33a** of the slit plate **33**, as well as to increase the average brightness of the arc images **350**.

As shown in FIG. **42(b)**, in the illumination system using the conventional concave lens, the arc images **350** are formed leaningly toward the center of the second integrator lens **32** relative to the respective central constituent cells **32a** of the second integrator lens **32**. Therefore, the slit plate **33** blocks a larger amount of light, which results in a problem of a smaller amount of light reaching the polarization beam splitter **34** at its central portion as shown in FIG. **43(b)**.

Accordingly, the light irradiation position for the cells **32a** of the second integrator lens **32** was eagerly examined with computer simulations and experiments. The result reveals that a larger amount of light is allowed to reach the polarization beam splitter **34** shown in FIG. **41** by, as shown in FIG. **42(a)**, moving the arc images **350** formed on the respective central constituent cells **32a** of the second integrator lens **32** outward relative to the center of the second integrator lens **32** from the position shown in FIG. **42(b)**.

Accordingly, as shown in FIG. **35(b)** and FIG. **41**, the concavity **80b** is formed only centrally on the light incidence surface of the concave lens **80**. As shown in FIG. **41**, the light incident on a central portion of the concave lens **80** is slightly refracted outward from the central portion by passing through the concavity **80b** of the concave lens **80**. The light having passed via the concavity **80b** and concave surface **80a** through the concave lens **80** passes through the central constituent cells **31a** of the first integrator lens **31**, and is imaged on the respective central constituent cells **32a** of the second integrator lens **32**. Due to the lens effect of the concavity **80b** of the concave lens **80**, the arc images imaged on the respective central constituent cells **32a** of the second integrator lens **32** are formed in positions moved outward relative to the center of the second integrator lens **32** as shown in FIG. **42(a)** from the position shown in FIG. **42(b)**.

Thus, as shown in FIG. **43(a)**, a larger amount of light reaches the polarization beam splitter **34** at its central portion than in the illumination system using the conventional concave lens shown in FIG. **43(b)**. Consequently, utilization efficiency of the light emitted from the lamp unit **7** can be improved.

When the lamp unit **7** having the ellipsoidal reflector **71** is used to constitute an illumination system, it is possible to improve utilization efficiency of the light emitted from the lamp unit **7** without causing an increase in the number of components because the concave lens **80** is an essential component. Further, the concavity **80b** has a simple shape, which makes it easy to work the concave lens **80**. In addition, the optical system **3** can be constructed using the two integrator lenses **31**, **32** having a plurality of cells **31a**, **32a** having a simple shape arranged in the form of a matrix, which can reduce production costs more than conventionally.

#### Cooling System **8**

The cooling system **8** for cooling a plurality of optical components constituting the image synthesizer **4** is, as shown in FIG. **4**, disposed below the image synthesizer **4** shown in FIG. **3**. The cooling system **8** includes two cooling fans **81**, **81** placed on the bottom surface of the lower half case **12** and a channel housing **82** constituting a channel for sending the outside air drawn from both cooling fans **81**, **81** toward the liquid crystal panels **43b**, **43g**, **43r** and incidence polarizing plates **41b**, **41g**, **41r** for the respective colors shown in FIG. **5**. The channel housing **82** has an upper surface thereof formed with air discharge openings **82b**, **82b**, **82g**, **82g**, **82r**, **82r** toward the liquid crystal panels **43b**, **43g**, **43r** and incidence polarizing plates **41b**, **41g**, **41r** for the respective colors. Both cooling fans **81**, **81** are disposed in the channel housing **82**.

Both cooling fans **81**, **81** have an air filter (not shown) attached to an outside air intake opening thereof in order to prevent dust from entering the inside of the device. The channel in the channel housing **82** is provided with a temperature sensor (not shown) for detecting the temperature of the outside air drawn from both cooling fans **81**, **81**.

As shown in FIG. **44**, the air filter **83** is attached to each of the cooling fans **81**, and each of the cooling fans **81** and the temperature sensor **84** are connected to a microcomputer **89**. The cooling fans **81** have a function of outputting a signal to change the on/off state each time it rotates a predetermined number of times (hereafter referred to as a revolutions detection signal). The revolutions detection signal and a temperature detection signal output from the temperature sensor **84** are captured into the microcomputer **89**.

Further connected to the microcomputer **89** are a fan drive circuit **85**, a memory **86**, and a warning means **88**. The microcomputer **89** feedback-controls the drive voltage to be given to the cooling fans **81** based on the temperature detection signal output from the temperature sensor **84** and the revolutions detection signal output from the cooling fans **81** such that the number of revolutions of the cooling fans **81** will be a certain number of revolutions in accordance with an outside air temperature **T**. The fan drive circuit **85** controls the drive voltage for driving the cooling fans **81** in response to instructions from the microcomputer **89**.

As shown in FIG. **45**, if the outside air temperature **T** is less than a predetermined temperature **T1**, for example, the cooling fans **81** are driven at a predetermined number of revolutions **r1**. On the other hand, if the outside air temperature **T** exceeds a predetermined temperature **T2**, the cooling fans **81** are driven at a predetermined number of revolutions **r2** greater than the number of revolutions **r1**. If the outside air tempera-



ture T is not less than T1 and not more than T2, they are driven at a predetermined number of revolutions r3 obtained by the following formula 1.

$$r3=(r2-r1)/(T2-T1)\times(T-T1)+r1 \quad \text{Formula 1:}$$

Besides the predetermined temperatures T1 and T2 and predetermined numbers of revolutions r1 and r2, the memory 86 shown in FIG. 44 stores a reference drive voltage V1 referred to when the cooling fans 81 are driven at the predetermined number of revolutions r1 and a reference drive voltage V2 referred to when the cooling fans 81 are driven at the predetermined number of revolutions r2.

The microcomputer 89 detects the outside air temperature T based on the temperature detection signal output from the temperature sensor 84. When determining that the outside air temperature T is lower than the predetermined temperature T1, the microcomputer 89 instructs the fan drive circuit 85 to give the cooling fans 81 the reference drive voltage V1, so that the cooling fans 81 will be driven at the reference drive voltage V1.

The microcomputer 89 then detects the number of revolutions Rf of the cooling fans 81 based on the revolutions detection signal output from the cooling fans 81. When determining that the number of revolutions Rf is smaller than the predetermined number of revolutions r1, the microcomputer 89 gives the fan drive circuit 85 instructions for changing the drive voltage to be given to the cooling fans 81 to the voltage (V1+ΔV) obtained by adding a predetermined voltage ΔV to the current drive voltage V1. Consequently, the cooling fans 81 will be driven at the drive voltage (V1+ΔV).

On the other hand, when determining that the number of revolutions Rf is greater than the predetermined number of revolutions r1, the microcomputer 89 gives the fan drive circuit 85 instructions for changing the drive voltage to be given to the cooling fans 81 to the voltage (V1-ΔV) obtained by subtracting the predetermined voltage ΔV from the current drive voltage V1. Consequently, the cooling fans 81 will be driven at the drive voltage (V1-ΔV). When it is determined that the number of revolutions Rf is equal with the predetermined number of revolutions r1, the drive voltage of the cooling fans 81 are maintained without being changed.

Repetition of the above steps maintains the number of revolutions of the cooling fans 81 at the predetermined number of revolutions r1.

Similarly, when the microcomputer 89 detects the outside air temperature T based on the temperature detection signal output from the temperature sensor 84, and determines that the outside air temperature T is higher than the predetermined temperature T2, the microcomputer 89 instructs the fan drive circuit 85 to give the cooling fans 81 the reference drive voltage V2, so that the cooling fans 81 will be driven at the reference drive voltage V2.

The microcomputer 89 then detects the number of revolutions Rf of the cooling fans 81 based on the revolutions detection signal output from the cooling fans 81. When determining that the number of revolutions Rf is smaller than the predetermined number of revolutions r2, the microcomputer 89 gives the fan drive circuit 85 instructions for changing the drive voltage to be given to the cooling fans 81 to the voltage (V2+ΔV) obtained by adding the predetermined voltage ΔV to the current drive voltage V2. Consequently, the cooling fans 81 will be driven at the drive voltage (V2+ΔV).

On the other hand, when determining that the number of revolutions Rf is greater than the predetermined number of revolutions r2, the microcomputer 89 gives the fan drive circuit 85 instructions for changing the drive voltage to be given to the cooling fans 81 to the voltage (V2-ΔV) obtained

by subtracting the predetermined voltage ΔV from the current drive voltage V2. Consequently, the cooling fans 81 will be driven at the drive voltage (V2-ΔV). When it is determined that the number of revolutions Rf is equal with the predetermined number of revolutions r2, the drive voltage of the cooling fans 81 are maintained without being changed.

Repetition of the above steps maintains the number of revolutions of the cooling fans 81 at the predetermined number of revolutions r2.

When the microcomputer 89 detects the outside air temperature T based on the temperature detection signal output from the temperature sensor 84, and determines that the outside air temperature T is between the predetermined temperature T1 and predetermined temperature T2, the predetermined number of revolutions r3 at which the cooling fans 81 are to rotate in the outside air temperature T is first calculated based on the formula 1. The microcomputer 89 then calculates a reference drive voltage V3 to be given to the cooling fans 81 with reference to the predetermined numbers of revolutions r1 and r2, reference drive voltages V1 and V2, and calculated predetermined number of revolutions r3, and instructs the fan drive circuit 85 to give the cooling fans 81 the reference drive voltage V3. Consequently, the cooling fans 81 will be driven at the reference drive voltage V3. For example, the reference drive voltage V3 is calculated by the following formula 2.

$$V3=(V2-V1)/(r2-r1)\times(r3-r1)+V1 \quad \text{Formula2:}$$

The microcomputer 89 then detects the number of revolutions Rf of the cooling fans 81 based on the revolutions detection signal output from the cooling fans 81. When determining that the number of revolutions Rf is smaller than the predetermined number of revolutions r3, the microcomputer 89 gives the fan drive circuit 85 instructions for changing the drive voltage to be given to the cooling fans 81 to the voltage (V3+ΔV) obtained by adding the predetermined voltage ΔV to the current drive voltage V3. Consequently, the cooling fans 81 will be driven at the drive voltage (V3+ΔV).

On the other hand, when determining that the number of revolutions Rf is greater than the predetermined number of revolutions r3, the microcomputer 89 gives the fan drive circuit 85 instructions for changing the drive voltage to be given to the cooling fans 81 to the voltage (V3-ΔV) obtained by subtracting the predetermined voltage ΔV from the current drive voltage V3. Consequently, the cooling fans 81 will be driven at the drive voltage (V3-ΔV). When it is determined that the number of revolutions Rf is equal with the predetermined number of revolutions r3, the drive voltage of the cooling fans 81 are maintained without being changed.

Repetition of the above steps maintains the number of revolutions of the cooling fans 81 at the predetermined number of revolutions r3.

If the air filters 83 of the cooling fans 81 are clogged due to long use, an insufficient amount of outside air is drawn from the cooling fan 81, while a certain amount of air is discharged outside the device from the exhaust fan 191 shown in FIG. 3. This gives a negative pressure in the channel housing 82, which in turn gives a small load when the cooling fans 81 rotate. In this case, the cooling fans 81 will receive a reduced drive voltage although the number of revolutions will not increase because the cooling fans 81 are driven at a predetermined number of revolutions determined depending on the outside air temperature T.

Accordingly, when the cooling fans 81 are driven at a predetermined number of revolutions determined depending on the outside air temperature T, the microcomputer 89 compares an actual drive voltage Vf given to the cooling fans 81



with the reference drive voltage  $V_{ref}$ , determines that the air filters **83** are clogged when the difference between both voltages is a certain value or more, gives a warning that the air filters **83** are clogged, and performs a protection operation of shutting off or reducing the power to be supplied to the lamp unit **7** lower than usual.

In FIG. **46**, the solid line indicates a relationship between the number of revolutions of the cooling fans **81** and the reference drive voltage  $V_{ref}$ , and the dashed line indicates a relationship between the number of revolutions of the cooling fans **81** and the drive voltage at which it is determined that the air filters **83** are clogged. The warning operation and protection operation will be performed when the difference between the reference drive voltage  $V_{ref}$  and actual drive voltage is a predetermined value  $V_4$  or more as shown in FIG. **46**.

FIG. **47** shows a control procedure to be performed by the microcomputer **89** during clogging detection for the air filters **83**. First, in step **S1**, the number of revolutions  $R_f$  of the cooling fans **81** are detected by the revolutions detection signal output from the cooling fans **81**. Based on the number of revolutions  $R_f$ , the drive voltage  $V_f$  to be given to the cooling fans **81** are feedback-controlled such that the cooling fans **81** are driven at a predetermined number of revolutions determined depending on the outside air temperature  $T$ . Then, in step **S2**, the drive voltage  $V_f$  is detected when the cooling fans **81** rotate at the predetermined number of revolutions. In step **S3**, an inquiry is made as to whether or not the difference between the reference drive voltage  $V_{ref}$  determined depending on the predetermined number of revolutions and the drive voltage  $V_f$  is greater than the predetermined value  $V_4$ . If the inquiry in step **S3** is answered in the negative, then step **S1** follows to continue the feedback control of the drive voltage  $V_f$  to be given to the cooling fans **81**.

If the inquiry in step **S3** is answered in the affirmative, then step **S4** follows to give a warning that the air filters **83** are clogged. The warning is given, for example, by lighting or flashing at least one of a plurality of warning lights constituting the warning portion **15** shown in FIG. **1**. Alternatively, a message that the air filters **83** are clogged may be displayed on a forward projection screen.

Step **S5** follows thereafter to shut off or reduce the power to be supplied to the lamp unit **7** lower than usual in order to suppress heat generation of a heat source of the lamp unit **7** to thereby perform the protection operation for preventing temperature rise of the liquid crystal panels **43b**, **43g**, **43r** and incidence polarizing plates **41b**, **41g**, **41r** for the respective colors shown in FIG. **5** to end the processing.

Step **S5** may perform a protection operation of increasing the number of revolutions of the cooling fans **81** higher than usual in order to suppress the reduction of the outside air drawn from the cooling fans **81** due to clogging of the air filters.

According to the above driving method for the cooling fans **81**, the cooling fans **81** are driven at a predetermined number of revolutions determined depending on the outside air temperature  $T$ , and therefore the cooling fans **81** draw an approximately constant amount of outside air regardless of individual differences of the cooling fans **81**. Therefore, there is no variation in the cooling effect of the cooling system **8** between liquid crystal projector devices, which can always provide a constant cooling effect regardless of individual differences of the cooling fans **81**.

In addition, clogging of the air filters **83** can be detected by comparing the actual drive voltage  $V_f$  of the cooling fans **81** with the reference drive voltage  $V_{ref}$ , which eliminates the necessity of a temperature sensor for detecting the temperature of the liquid crystal panels **43b**, **43g**, **43r** and incidence polarizing plates **41b**, **41g**, **41r** for the respective colors shown in FIG. **5** unlike in conventional devices.

The present invention is not limited to the foregoing embodiment but can be modified variously by one skilled in the art without departing from the spirit of the invention as set forth in the appended claims. For example, as shown in FIG. **26**, while the lamp unit **7** of the present embodiment has the third air introduction opening **73** provided between the first and second air introduction openings **74a**, **74b** and opened toward the end of the lamp bulb **170**, the third air introduction opening **73** may be excluded if a sufficient cooling effect can be provided.

What is claimed is:

1. A projector device comprising:

a lamp unit providing a light source;  
a cooling fan for cooling the lamp unit; and  
an optical system for generating color image light with the lamp unit providing the light source,

the lamp unit comprising

a columnar lamp bulb having a luminous body enclosed therein; and

a reflector for reflecting light emitted from the lamp bulb toward the optical system,

wherein the projector device is capable of taking a plurality of set postures including a first set posture where the lamp bulb of the lamp unit extends approximately horizontally, and a second set posture where the projector device is rotated around an axis of the lamp bulb by 90 degrees from the first set posture,

wherein a first air introduction opening and a second air introduction opening are provided in a side wall of the lamp unit opposed to the cooling fan and at opposite sides of a plane including a central axis of the lamp bulb and perpendicular to the side wall, the first air introduction opening and the second air introduction opening introducing air in a direction parallel to the plane, and air discharged from the cooling fan is blown to the lamp bulb through the both air introduction openings, and

wherein the air discharged from the cooling fan is separated by a part of the side wall between the first air introduction opening and the second air introduction opening so that air introduced from the first air introduction opening flows above the lamp bulb in a space inside the reflector with a boundary located on the plane and air introduced from the second air introduction opening flows below the lamp bulb in a space inside the reflector with a boundary located on the plane.

2. The projector device according to claim 1, wherein the first air introduction opening and the second air introduction opening are open toward a light emitting portion of the lamp bulb, and a third air introduction opening open toward an end of the lamp bulb is provided between the first and second air introduction openings in the side wall.

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